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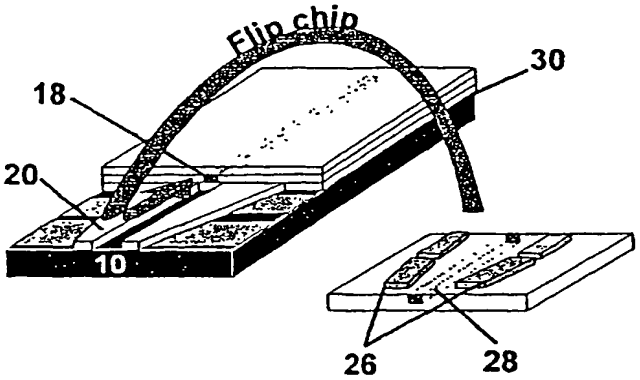
(54) Title: HYBRID INTEGRATION OF ACTIVE AND PASSIVE OPTICAL COMPONENTS ON AN SI-BOARD



(57) Abstract: The present invention relates to an assembly structure and a method for assembling active and passive photonic and/or optoelectronic devices on a silicon board. The invention relates in particular to an assembly structure and a method for aligning the photonic devices during the assembling procedure. According to the present invention, the assembly structure comprises one or more alignment features comprising tapered side surface parts in directions at least substantially parallel to an optical axis. By providing a tapering in a direction at least substantially parallel to the first optical axis, any inaccuracies primarily affects the non-critical positioning in the direction along the optical axis, whereas the critical positioning transverse to the optical axis merely depends on the symmetry of alignment features. The errors from the inherent inaccuracy of the position and shape of alignment features are thereby minimised. Also, the devices to be aligned are preferably arranged on top of the alignment features which forms part of the basic structure on the silicon board. All alignment features can thereby be defined in a single mask step together with the structures with which the alignment is to be carried out, resulting in an improved accuracy of the assembly structure. The resulting components will be used especially for broadband telecommunication components.

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Hybrid Integration of Active and Passive Optical Components on a Si-Board

This invention relates to an assembly structure and a method for assembling active and passive photonic and/or optoelectronic devices on a silicon board. The invention relates in particular to an assembly structure and a method for aligning the photonic devices during the assembling procedure. The resulting components will be used especially for broadband telecommunication components.

The assembly of photonic components is a very difficult and costly process. State of the art technology positions an optical fibre relative to a photonic component by an active alignment procedure. This means that during the alignment procedure the components are manipulated by highly accurate stages (±0.1µm). The incoming or outgoing light signal is monitored during micromanipulation until the optimum of transmitted light has been determined. Then the fibre is mechanically fixed employing different techniques. The last assembly step is to put the fibre-terminated component into a housing, which then can be hermetically sealed in order to protect the semiconductor component. The housing provides electrical as well as optical feed-throughs. The fabrication of feed-throughs for the optical fibre is a process, which is difficult to manufacture, too.

The assembly is of photonic components is, due to the very demanding manufacturing steps time consuming and makes up typically 80% of the device cost. Much could be won if one used planar light guiding circuits (PLCs) for broadband telecommunication systems not only as passive components. PLCs have a very attractive potential to increase functionality by directly mounting semiconductor components onto the PLC board. But most importantly this concept, which in the literature is referred to as hybridisation could also facilitate the assembly of components and the subsequent hermetic sealing components to a high degree.

A typical application of a hybridly integrated photonic component is shown in Fig. 1 where a pump laser device 2 is attached onto a PLC board 10, which also hosts a waveguide 4 leading the light from the laser to other parts of an planar lightwave circuit (PLC). The alignment and assembly of the semiconductor component is achieved by a simple "clip-

on" procedure, which does not require active alignment and therefore will greatly decrease assembly costs.

An inherent advantage of the hybrid integration concept is that it allows the light from the pump laser to be coupled directly into the waveguide whereas with conventional technologies each component has to be connected to a fibre separately, put into a housing and be connected using optical fibre connectors. The state-of-the art concept leads to bulky and difficult-to-handle components whereas the hybridisation leads to highly integrated and compact modules.

In the efforts to fully exploit the potential of PLCs one question is key; how does one obtain a long-term mechanical stability between the photonic component and the waveguide structure on the PLC board, and how can the active alignment procedure be avoided? This question has created a technical challenge for the fiberoptics components industry. The necessary coupling tolerance is in the submicron region and the fixation needs a mechanical stability of less than +/- 0.1μm under all possible operation- and storage- conditions.

In the prior art there are several attempts to achieve fastening of photonic components such as lasers to a PLC board by passive alignment.

Methods using highly accurate Flip-Chip Bonding machines have been developed. These make use of optical detection of fiducials (alignment marks) on the substrate and photonic component. Registration and positioning are however time consuming and equipment is very expensive.

Self-aligned bonding which make use of micromachined V-grooves for fibre fixation and the surface tension forces of the molten solder material, has been proposed and taken up by research facilities around the world. The method has been proven to reach the required tolerances. Nevertheless, the needed accuracy, which is within 1 μm, requires extremely well controlled process tolerances on soldering and V-groove micromachining, which will be costly to develop.

One of the alignment concepts that make use of etched alignment structures and surface tension forces of the molten solder material, is presented in US 5,656,507. Here the

silicon substrate is prepared with a waveguide, two alignment stops, a V-shaped groove and a trench with an L-shaped metal pad in the bottom. The bottom of the laser holds a ridge and an L-shaped metal pad with a solder bump so as to fit the V-shaped groove and the L-shaped metal pad on the silicon substrate. The principle is that when the laser is placed on the silicon substrate with the ridge inserted in the groove and an edge abutted to the alignment stops, the two L-shaped metal pads are slightly displaced though connected by the solder bump. When the solder is melted, it will draw the laser into alignment with the waveguide through surface tension forces.

Many companies have shifted their focus to alignment concepts, which require highly accurate pick and place machines in conjunction with alignment fiducials on the assembled parts (see H.L. Althaus et. al., "*Microsystems and Waferprocesses for Volumeproduction of Highly Reliable Fibre Optic Components for Telecom and Datacom Applications*", 47th ECTC Conf., San Jose, CA, 1997, pp. 7-15). These concepts are very application specific and require large investments that only pay off for large production volumes. Parallel to that, an increasing number of publications emerged proposing a concept which makes use of dry- or wet-etched alignment structures, e.g. D. A. Ackerman (US 5,023,881), J. Gates et al. (*"Hybrid Integrated Silicon Optical Bench Planar Lightguide Circuits"*, 48th ECTC Conf., Seattle, WA, 1998, pp. 551-559) and S. A. Merrit (*"A Rapid Flip-Chip Bonding Method for Semiconductor Laser Diode Arrays"*, 48th ECTC Conf., Seattle, WA, 1998, pp. 775-779).

US 5,023,881 covers the use of pedestals which initially forms a gap in-between the laser and the substrate. The vertical alignment is achieved by placing the laser on top of two pedestals, and the precision relies on the thickness of numerous individual layers. The specific alignment step consists of a cold welding for tacking the laser during the subsequent soldering. The horizontal alignment is not addressed in this patent and needs to be realised presumably by micromanipulation ("in a predetermined way").

Another alignment concept, which makes use of etched alignment structures, is presented in US 5,721,797. The patent discloses a method for aligning a laser relative to a fibre or a waveguide. Here, only the method relating to the waveguide is of interest. Two trenches are etched into the silicon substrate to later host waveguide structure (1st trench) and laser-mounting site (2nd trench). Then the second trench is filled with solder material, the first trench with cladding material for the optical waveguide. The procedure ensures that

the waveguide core is at the same height as the light emitting core of the laser waveguide (vertical alignment). At the same time as the waveguide core material three alignment stops are formed to which the laser component will abut during assembly in order to achieve the horizontal alignment. The fabrication step is finalised by putting the top cladding onto the core waveguide material.

When the laser is then mounted on top of the solder (deposited into the 2nd trench) the component is slithered towards the three alignment structures to ensure horizontal alignment. It is important to note that it is the sides of the laser, which abut the alignment stops, and the thickness of the solder deposition, which defines the horizontal and vertical alignment respectively. Applying heat to the assembly, thereby melting the solder the laser is mechanically fixed onto the silicon substrate.

Often, hybrid integration apparatuses are not compatible with the diversity of photonic devices from different manufacturers. Most of the prior art implies certain dimensions and features of the devices in order to perform the hybrid integration (US 5,721,797). If the design of the device is changed the assembly structure needs to be changed as well. The situation in a production advanced PLCs will be that that the dimensions of photonic devices change. It will be too expensive and time-consuming to make adjustments to the assembly structures.

It is a disadvantage of the existing alignment concepts (US 5,721,797) that the accuracy of the horizontal alignment relies on the precision etching of the alignment structures and on precision cleaving of the laser components. The required precision of both technologies is in a critical range for manufacturing (<1µm).

It is a disadvantage of the existing alignment concepts (US 5,721,797) that during melting of the solder to fasten the laser onto the PLC board the surface tension forces of the molten solder can move the laser chip and thus destroy the horizontal and especially the vertical alignment.

It is a disadvantage of the existing alignment concepts (US 5,023,881) that the horizontal alignment of the components requires registration of alignment marks and accurate and thus costly micromanipulation to achieve the horizontal alignment.

It is a still further disadvantage of the existing alignment concepts (US 5,023,881 and US 5,721,797) that the vertical alignment relies on the thickness of several individual material layers (e.g. solder deposits) which need to be accurately deposited in relation to the thickness of a reference layer, which is the waveguide core of the PLC.

It is an object of the present invention to provide an assembly structure and a method for self-aligned hybrid assembly in which alignment can be realised before fastening.

It is another object of the present invention to provide an assembly structure and a method for self-aligned hybrid assembly in which reworking in case of a malfunctioning photonic components is possible, since the malfunctioning component can be detached by heating the structure, and replaced by a new component.

It is still another object of the present invention to provide an assembly structure and a method for self-aligned hybrid assembly, which implies only a minimum of "add-on" features to the photonic device, and does not require certain dimensions of the photonic device.

It is still another object of the present invention to provide an assembly structure and a method for self-aligned hybrid assembly where no processing, such as etching of the often fragile photonic device is needed.

It is still another object of the present invention to provide an assembly structure and a method for self-aligned hybrid assembly where the horizontal alignment relies on a single mask step in a photolithographic process.

It is still another object of the present invention to provide an assembly structure and a method for self-aligned hybrid assembly where the vertical alignment relies on the positioning of aligned components on what are essentially different parts of the same surface.

It is still another object of the present invention to provide an assembly structure and a method for self-aligned hybrid assembly where no accurate cleaving is needed since no cleaved surfaces abut during alignment.

It is still another object of the present invention to provide an assembly structure and a method for self-aligned hybrid assembly of photonic components, which is compact and thereby easy to pack and stack.

It is still another object of the present invention to provide an assembly structure and a method for self-aligned hybrid assembly of an array of photonic devices on a substrate.

It is still another object of the present invention that a hermetic sealing of the semiconductor component can be integrated into the processing, using basically the same masks, materials and processing steps used to form the assembly structure.

The above-mentioned objects are complied with by providing in a first aspect of the present invention an assembly structure comprising:

- a substrate holding a bottom cladding layer, said bottom cladding layer comprising a first and a second part, wherein each part comprises a top and a bottom surface separated by a distance d,

- an optical waveguide comprising a top and a bottom surface and a light input or output end, said optical waveguide defining a first optical axis, the bottom surface of said optical waveguide being positioned at a distance larger than or equal to d above the bottom surface of the bottom cladding layer, and

- one or more first alignment features being formed in the second part of the bottom cladding layer, said one or more first alignment features further comprising a first and a second tapered side surface part in directions at least substantially parallel to the first optical axis.

The top surface of the first alignment features is essentially in the same plane as the top surface of the first part of the bottom-cladding layer. In order to confine light within the optical waveguide an additional material is provided to embed the waveguide core.

The assembly may further comprise a set of electrical contact pads suitable for providing electric energy to an optoelectronic device such as a semiconductor laser, a light emitting diode (LED) or a photodiode.

Preferably, the bottom surface of the optical waveguide core is positioned on the top surface of the bottom cladding layer at a distance substantially equal to d, where d is measured from the bottom surface of the bottom cladding layer.

The assembly structure according to the first aspect of the present invention may further comprise

- an optoelectronic device comprising an active part and a light input or output port, said input or output port being optically aligned with the waveguide output or input end by having the optoelectronic device arranged on top of the first alignment features to thereby obtain vertical alignment.

By arranging the optoelectronic device on top of the alignment features, a vertical alignment is achieved between the active part of the device and the waveguide. However, the active part of the device may be positioned at a given height above the bottom surface of the device, whereby the light input or output port will be positioned at a given height over the bottom-cladding layer when the device is arranged on top of the alignment features. Depending on this given height, and upon the respective sizes of the input/output port and the waveguide end, the waveguide may be positioned at a distance $d+x$ above the bottom surface of the bottom cladding layer, where x compares to the given height of the active part in the optoelectronic device. The distance x may be controlled by depositing one or more material layers between the bottom-cladding layer and the waveguide core.

In order to horizontally align the light receiving input end of the optical waveguide with the light output port of the optoelectronic device, the assembly structure may further comprise one or more second alignment features abutting the one or more of the first alignment features of the second part of the bottom cladding layer. Preferably, the second alignment features abut the first and second tapered side

surface parts of the first alignment features whereby the horizontal alignment is performed in the direction transversely to the optical axis of the waveguide.

The tapered surface parts provide an improved horizontal alignment on several points. The abutting of the second alignment features to the tapered side surface parts wedges the optoelectronic device to the structure and thereby provides a steady fixation until the devices is properly secured. Moreover, the orientation of the tapered side surface parts improves the accuracy in the critical positioning parameters of the optoelectronic device in relation to the waveguide. In the horizontal alignment, the direction transversely to the optical axis of the waveguide is very critical in order for light to couple between the waveguide and the active region. However, the distance between waveguide and the active region along the optical axis is considerably less critical. By providing a tapering in a direction at least substantially parallel to the first optical axis, the inherent inaccuracy of the position and shape of the first and second alignment features primarily affects the less critical distance between the waveguide and the active region.

For example, the optoelectronic device may be a light source comprising a light output port, an active part and one or more second alignment features being adapted to abut one or more of the first alignment features of the second part of the bottom cladding layer so as to align the light receiving input end of the optical waveguide with the light output port of the light source.

Etching may be applied to fabricate the assembly structure. In order to control the etching process an etch stop layer may be provided at some stage during the fabrication process on top of the first alignment features. In an embodiment according to the invention the etch stop layer is maintained on top of the first alignment features thereby arranged below the optoelectronic device.

It is preferred that during the formation of the assembly structure, the positioning of the optical waveguide and the first alignment features is defined using a single mask. The reason for this being that for every mask being involved in the fabrication process an uncertainty is introduced in the positioning of one mask relative to another mask.

The second alignment features may comprise solder stripes arranged on the bottom of the optoelectronic device so as to at least partly engage the side walls of the first alignment features. Preferably, at least two solder stripes are arranged on the bottom of the optoelectronic device. In order to provide electrical power to the optoelectronic device the optoelectronic device may be soldered to metallized contact pads formed on exposed parts of the substrate.

As long as the solder stripes are positioned symmetrically, any inaccuracy in their separation or size will change the gap between the optoelectronic device and the waveguide, but not result in transverse misalignment. This means that if there is a tolerance in the width of the symmetrically designed 2 solder stripes the horizontal alignment will be unaffected whereas the less critical distance between waveguide and optoelectronic device will be changed according to the taper angle.

Preferably, two of the first alignment features provides the first and second tapered side surface parts on outer side surfaces, and the alignment features may be separated by a distance larger than the width of the active part of the optoelectronic device.

As already mentioned, the optoelectronic device may comprise a variety of light sources, such as a semiconductor laser or a diode.

In a second aspect, the present invention relates to a method of forming an assembly structure for assembling an optoelectronic device and an optical waveguide, said optical waveguide comprising a light input end for receiving light emitted from an output port of the optoelectronic device, said method comprising the steps of:

- providing a bottom cladding layer on top of a substrate, said bottom cladding layer comprising a first and a second part, wherein each part comprises a top and a bottom surface separated by a distance d,

- providing a core layer on top of at least part of the bottom cladding layer,

- forming the optical waveguide in the core layer, said optical waveguide thereby extending along a first optical axis in a plane and at a distance larger than or equal to d from the bottom surface of the first part of the bottom cladding layer, and

- forming one or more first alignment features in the second part of the bottom cladding layer so that at least one top surface of the first alignment features is in essentially the same plane as the top surface of the first part of the bottom cladding layer, the step of forming the one or more first alignment features comprises the step of forming a first and a second tapered side surface part in directions at least substantially parallel to the first optical axis.

The method according to the second aspect of the present invention may further comprise the step of:

- aligning the output port of the optoelectronic device with the light input end of optical waveguide, said alignment comprising the step of arranging the optoelectronic device on top of the one or more alignment features so as to obtain vertical alignment.

The optical waveguide may extend on the top surface of the bottom-cladding layer at a distance substantially equal to d above the bottom surface of the bottom-cladding layer.

As mentioned in relation with the first aspect of the present invention the optoelectronic device may further comprise one or more second alignment features abutting the first and second tapered side surface parts of the first alignment features so as to horizontally align the light receiving input end of the optical waveguide with the light output port of the optoelectronic device. By providing the tapering in a direction at least substantially parallel to the first optical axis, the inherent inaccuracy of the position and shape of the first and second alignment features primarily affects the less critical distance between waveguide and the active region. Again, it is preferred that the positioning of the optical waveguide and the first alignment features are defined using a single mask.

The method according to the second aspect of the present invention may even further comprise the step of providing an etch stop layer on at least part of the second part of the bottom cladding layer prior to deposition of the core layer, said core layer extending on both the first and the second part of the bottom cladding layer thereby covering at least part of the etch stop layer.

The formation of the optical waveguide and the first alignment features preferably comprises the steps of:

a) defining the horizontal configuration of the optical waveguide and the first alignment features in the core layer by a single mask process,

b) partially removing the core layer thereby forming the optical waveguide and defining the first alignment features in the core layer,

c) removing that part of the etch stop layer not being covered by the core layer,

d) providing a top cladding layer so as to at least partly cover the optical waveguide and optionally the one or more alignment features formed in the core layer, and

e) removing the top-cladding layer, the core layer and at least part of the second part of the bottom cladding layer to thereby form the first alignment features in the bottom-cladding layer.

The etch stop layer defining the one or more alignment features formed in the bottom cladding layer may optionally be totally removed or only partly removed. If the etch stop layer is only partly removed the remaining layer may be used to adjust the height of the optoelectronic device relative to the optical waveguide.

The removing in step e) may comprise etching the second part of the bottom cladding layer so as to expose that part of the substrate not being covered by the

first alignment features. Preferably, the etching process involves an anisotropic etch, such as reactive ion etching.

Preferably, the first alignment features comprises two alignment features having outwardly tapered side surface parts, said two alignment features being separated by a distance larger than or equal to the width of the active part of the optoelectronic device. The one or more second alignment features are arranged on the bottom of the optoelectronic device so as to at least partly engage the outer side walls of the first alignment features while aligning the optoelectronic device. The second alignment features may comprise solder stripes so as to electrically connect the optoelectronic device to e.g. a power supply. Preferably, at least two solder stripes are arranged on the bottom of the optoelectronic device.

The method according to the second aspect of the present invention may further comprise soldering the optoelectronic device to one or more electrical contact pads formed beside the alignment features on exposed parts of the substrate. Preferably, soldering is performed by applying heating the solder stripes above a certain melting temperature. If e.g. a bad connection has been established during soldering, or the optoelectronic device turns out to be malfunctioning, the device may be removed by heating the assembly and thereafter replaced with new device.

The optoelectronic device may comprise any kind of light source, such as a laser diode or an LED. The laser diode may be a semiconductor laser diode.

In a third aspect, the present invention relates to an assembly structure comprising:

- a substrate having one or more first alignment features disposed thereon, and

- a first photonic device having a light input or output port for receiving or emitting light along a first optical axis, and having a bottom surface having one or more second alignment features disposed thereon,

the assembly structure being characterised in that:

the one or more first or second alignment features forms a first and a second side surface part which are tapered in directions at least substantially parallel to the first optical axis, and

the first photonic device is positioned on top of at least one of the one or more first alignment features, whereby two or more surface parts of the one or more first alignment features abuts two or more surface parts of the one or more second alignment features, the abutting surface parts comprising the first and second side surface parts.

As in the case of the first aspect, providing a tapering in a direction at least substantially parallel to the first optical axis, the inherent inaccuracy of the position and shape of the first and second alignment features primarily affects the less critical positioning along the first optical axis.

The assembly structure according to the third aspect of the present invention may further comprise:

- a second photonic device comprising a light input or output port for receiving or emitting light along a second optical axis, and comprising a bottom surface having one or more second alignment features disposed thereon, wherein

the one or more first or second alignment features provides a third and fourth side surface part which are tapered in directions at least substantially parallel to the second optical axis, and

the second photonic device is positioned on top of at least one of the one or more first alignment features, whereby two or more surface parts of the one or more first alignment features abuts two or more surface parts of the one or more second alignment features, the abutting surface parts comprising the third and fourth side surface parts.

The light input or output port of the first and/or second photonic device may have a predetermined orientation and height with respect to the substrate. This predeter-

mined orientation and height determines the optical axis along which the photonic device may receive or emit light. In most cases, a photonic device does not define one unique optical axis since it may receive or emit light propagating along a small range of directions such as directions within a cone radiating from the input or output port. Hence in such cases the first optical axis may be defined as the centre axis of such a cone. Alternatively, the optical axis may be defined by other features of the assembly structure such as another input or output port coupling light to/from the photonic device.

In one example, the first photonic device comprises a light input port and the second photonic device comprises a light output port. The photonic devices are positioned so as to align the light input port of the first photonic device with the light output port of the second photonic device. This example could be the situation where a light source, such as a semiconductor laser or an LED, is aligned with a light receiving input end of an optical waveguide, such as an optical fibre or a planar waveguide, so as to couple electromagnetic radiation from the optoelectronic device to the optical waveguide. In this case the first optical axis may be defined as the straight line between the output and the input ports.

In another example, the first photonic device and the second photonic device both have a light output port, and the photonic devices are positioned so as to align the two light output ports along two parallel optical axes. This example could be the situation where two semiconductor laser diodes, are to be aligned relative to each other so as to e.g. emit two substantially parallel beams of electromagnetic radiation.

The second alignment features of the first and/or second photonic device may comprise one or more solder stripes. Preferably, at least two solder stripes are arranged on the bottom of a photonic device.

A photonic device may comprise an active waveguide component, such as an optical amplifier, such as a fibre amplifier.

In a fourth aspect, the present invention relates to a method of forming an assembly structure, said method comprising the steps of:

- providing a substrate having one or more first alignment features disposed thereon,

- providing a first photonic device having a light input or output port for receiving or emitting light along a first optical axis, and having a bottom surface having one or more second alignment features disposed thereon, wherein

the one or more first or second alignment features forms a first and a second side surface part which are tapered in directions at least substantially parallel to the first optical axis,

the method further comprising the step of:

- positioning the first photonic device on top of at least one of the one or more first alignment features, whereby two or more surface parts of the one or more first alignment features abuts two or more surface parts of the one or more second alignment features, the abutting surface parts comprising the first and second side surface parts.

Again, providing a tapering in a direction at least substantially parallel to the first optical axis, the inherent inaccuracy of the position and shape of the first and second alignment features primarily affects the less critical positioning along the first optical axis. Either of the first or second alignment features held by the substrate or by the photonic device may comprise the tapered side surface parts. Optionally, both the first and second alignment features are tapered.

The method may further comprise the steps of:

- providing a second photonic device comprising a light input or output port for receiving or emitting light along a second optical axis, and comprising a bottom surface having one or more second alignment features disposed thereon, wherein

the one or more first or second alignment features provides a third and fourth side surface part which are tapered in directions at least substantially parallel to the second optical axis, and

- positioning the second photonic device on top of at least one of the one or more first alignment features, whereby two or more surface parts of the one or more first alignment features abuts two or more surface parts of the one or more second alignment features, the abutting surface parts comprising the third and fourth side surface parts.

For most applications the light input or output port of a photonic device has a predetermined orientation and height with respect to the substrate. This predetermined orientation and height determines the optical axis along which the photonic device may receive or emit light

Different schemes may arise. The first photonic device may have a light input port whereas the second photonic device may have a light output port. The situation may also be that the first photonic device and the second photonic device may both have a light output port. In both cases the first and second photonic devices are positioned relative to each other so as to align the input/outputs so that electromagnetic radiation propagates substantially along at least one predetermined optical axis.

Preferably, the height of the first alignment features may be adjusted so as to obtain vertical alignment. The engagement of the first alignment features and the second alignment features ensures horizontal alignment. Thus both vertical and horizontal alignment can be achieved prior to fixation of a photonic device.

Preferably, it is the first alignment features, held by the substrate, which provides the tapered side surface parts. In order to provide aligned of the first and second photonic device, the first alignment features providing the first to fourth tapered side surface parts are formed in a single mask step. The second alignment features of the first and/or second photonic device may comprise one or more solder stripes. Preferably, at least two solder stripes are arranged on the bottom of each photonic device.

A photonic device may comprise a passive optical component, such as an optical waveguide, such as an optical fibre or a planar waveguide. A photonic device may also comprise an optoelectronic device, such as a laser diode or an LED. Finally, a photonic device may comprise an active waveguide component, such as an optical amplifier. In order to achieve amplification, the active waveguide may comprise rare-earth materials, such as erbium.

In yet another aspect, the invention relates to an assembled structure comprising a first, lower structure part and a second, upper structure part, wherein:

- the first structure part comprises:
  - a first substrate, an upper surface of which defines a first plane, the substrate comprising a first and a second part
  - a first radiation guiding, emitting, and/or receiving means positioned on or above the first part of the first substrate and in a fixed relation thereto, the means defining a first optical axis extending at least substantially parallel to the first plane,
  - one or more first alignment elements positioned on or above the second part of the first substrate, the one or more first alignment elements having one or more upper surface parts being in a fixed relationship to the first optical axis and the first plane, and the one or more first alignment elements having one or more side surface parts being positioned in a predefined position in relation to the first optical axis,

- the second structure part comprises:
  - a second substrate having a lower surface defining a second plane being at least substantially parallel to the first plane,
  - a second means for guiding, emitting, and/or receiving radiation, the means defining a second optical axis and being positioned below the second substrate and in a fixed relation thereto,

- one or more second alignment elements positioned below the second substrate, and the one or more second alignment elements having one or more side surface parts being positioned in a predefined position in relation to the second optical axis,

the second structure part having one or more lower surface parts being in a fixed relationship to the second optical axis and the second plane,

the one or more first and second alignment elements being relatively positioned so that, when the first and second optical axes are at least substantially coincident:

- at least part of the one or more upper surface parts of the one or more first alignment elements abut at least part of the one or more lower surface parts of the second structure part,
- at least part of the one or more side surface parts of the one or more first alignment elements abut at least part of the one or more side surface parts of the one or more second alignment elements, and
- the abutting side surface parts of at least one of the one or more first and second alignment elements comprising at least two surface parts extending in different planes, at angles different from 0 and 90 degrees from the first optical axis.

This has the advantage that the abutting side surface parts and upper and lower surface parts may be positioned so as to, when projected perpendicularly onto the first plane, reside within an area within the first plane, the area being defined as the overlap between the first and second parts when these are projected perpendicularly onto the first plane. Thus, all engaging parts or surfaces may not comprise any parts of those edges of the structure part created by separation following a mass manufacturing of such structure parts.

Normally, a large number of such structure parts are prepared in the same process and on the same wafer. Separation is performed subsequently by simply cutting or breaking the wafer with the structure part. Such separation will normally not result in edges which have well defined positions and distances in relation to e.g one or more light guides or the like in the structure parts.

As mentioned above, it may be desired that the first and second parts each further comprises a set of electrical contact pads positioned so as to abut or engage and thereby provide electrical contact between the contact pads of the first and second parts.

In a preferred embodiment, the second alignment elements comprise at least one, such as at least two, solder stripes, and the first structure element comprises at least one contact pad positioned so as to abut or engage the at least one solder stripe of the second part. In this situation, the first and second structure parts may be fixedly interconnected at least in part by an engagement, such as a soldering, between the solder stripe(s) and contact pad(s).

Naturally, the overall positioning and fastening of the two structure parts entails no demands as to the function or operation of the two radiation guiding, emitting, and/or receiving means of the two structure parts. Thus, the radiation guiding, emitting, and/or receiving means of at least one of the first and second structure parts may, e.g., comprise:

- a waveguide, such as an optical fibre or a planar waveguide, where the optical axis is defined by a longitudinal axis of the waveguide,
- a light emitter, such as a semiconductor laser diode or an LED, and where the optical axis is defined as an axis of symmetry of radiation emitted by the light emitter, and/or
- an active waveguide component, such as an optical amplifier, such as a fibre amplifier, where the optical axis is defined by a longitudinal axis of the waveguide.

One of the advantages of the present assembly may be seen, as, in the first structure part, the one or more upper surface parts may define a plane at least substantially comprising a lower side of the first means for guiding, emitting and/or receiving radiation. This provides the advantage, as mentioned above, that the inter-positioning thereof may be obtained with a good precision.

In order to obtain a precise and reproducible positioning of the structure parts, the abutting side surface parts of one of the first and the second structure part preferably define an outwardly tapered part, viewed from the respective means for guiding, emitting, and/or receiving radiation and wherein the abutting side surface parts of the other of the first and the second structure part preferably define an inwardly tapered part, viewed from the respective means for guiding, emitting, and/or receiving radiation. In this manner, the two tapered parts may be adapted to fit in a manner so that a quick and error-free connection is obtained.

In that situation, it is preferred that, in one or both of the first and second structure part, the one or more alignment elements are positioned so as to provide a space at least corresponding to a cross section of an active part of the means for guiding, emitting, and/or receiving radiation, the cross section being translated along the respective optical axis over the second part of the respective structure part. In that manner, radiation guiding, emitting, and/or receiving means having such dimensions may be positioned in that space in order to optically fit the other radiation guiding, emitting, and/or receiving means.

In yet another aspect, the invention relates to a first and/or a second structure part for use in the assembled structure.

Also, an aspect of the invention relates to a method of manufacturing a first structure part for use in the assembled structure, the method comprising:

1. providing a substrate having a first and a second part,
2. providing a means for guiding, emitting, and/or receiving light, the means defining an optical axis, the means being positioned on or above the first part of the substrate and so as to be fixed in relation to the substrate and so that the optical axis is in a predetermined relation to the substrate,
3. providing one or more alignment elements on or above the substrate, the one or more alignment elements being positioned:
   - on or above the second part of the substrate,
   - so that the one or more alignment element has/have one or more upper surface parts being in a fixed relationship to the first optical axis and the first plane, and

- so that the one or more first alignment element has/have one or more side surface parts being positioned in a predefined position in relation to the first optical axis.

Preferably, steps 2) and 3) comprise the steps of:

I. providing a first layer of a first material on or over at least substantially all of an upper surface of the first and second parts of the substrate, the first material having a first effective refractive index,

II. providing a second layer of a second material on at least substantially all of an upper surface of the first layer and at least over or at the first part of the substrate, the second material having a second effective refractive index being different from the first effective refractive index, and

III. removing a predetermined part of the second layer.

Advantageously, steps 2) comprises providing between steps I) and II), a third layer of a third material on the upper surface of the first layer and at least over or at the second part of the substrate. Preferably, the third material are adapted to withstand a process of removing at least part of the first layer.

Also, it is desired that:

- step II) comprises providing the second layer also on the third layer,
- step III) comprises the steps:
  a) predefining the parts, both over or at the first and second parts of the substrate, of the second layer which should be removed,
  b) removing the predefined parts of the second layer.

In that situation, step 2) may comprise providing, at least over or at the first part of the substrate, a fourth layer of a fourth material on the structure resulting after step b), the fourth material having a refractive index being different from the second refractive index.

Step III) may further comprises removing those parts of the third layer on which predefined parts of the second layer are positioned.

In that situation, step 3) preferably further comprises removing all remaining parts of the second layer on or above the second part of the substrate.

Also, step 2) preferably further comprises removing at least substantially all parts of the first layer, which parts correspond to parts of the third layer removed during step b).

Preferably, step III) further comprises removing at least substantially all remaining parts of the third layer above or at the second part of the substrate.

A major advantage of the invention is that step a) may comprise predefining the parts in a single step. Naturally, this may be obtained using virtually any technique. However, at present, it is preferred to use a lithographic process and by using a single mask.

It is also preferred that the further removing step of step 3) is performed using a predefined removal procedure, such as an etching procedure, such as reactive ion etching, and wherein step II) comprises providing a third layer of a third material, such as an etch stop, which is adapted to not be removed during the predefined removal step.

Yet another aspect of the invention relates to a method of assembling an assembled structure according to claim 1, the method comprising:

- providing the first and second structural parts, then
- positioning the first and second structural parts in order to form the assembly, and finally
- fixing the first and second structural parts to each other.

This firstly positioning and then fixing the parts has a number of obvious advantages, e.g. that proper functioning of each part can be checked before fixing which may be an irreversible process.

In the following, the present invention will be described in further detail with references to the figures listed below.

Fig. 1 shows typically optical chip including a hybrid integrated pump laser and a waveguide.

Fig. 2 shows the first step of fabricating the assembly structure, in which a bottom cladding is deposited on a silicon substrate.

Fig. 3 shows a polysilicon etch stop applied on part of the bottom cladding.

Fig. 4 shows a layer of core glass applied on the structure of Fig. 3.

Fig. 5 shows the structure of Fig. 4 after an etching step defining the waveguide and alignment taper templates.

Fig. 6 shows the structure of Fig. 5 after removal of the accessible polysilicon etch stop.

Fig. 7 shows several top cladding layers applied on the structure of Fig. 6.

Fig. 8 shows the structure of Fig. 7 after removal by etching of the front part of the top cladding and alignment taper templates.

Fig. 9 shows continued etching of the structure of Fig. 8 completing the alignment tapers.

Fig. 10 shows metal pads serving as laser electrodes and thermal paths applied on the structure of Fig. 9.

Fig. 11 shows a photonic device to be applied on top of the structure of Fig. 10.

Fig. 12 shows the aligned assembled structure while melting the solder stripes for fastening.

Fig. 13 shows an exploded view of the structure of Fig. 12 revealing the melted solder stripes.

Fig. 14 is a front view of the aligned assembled structure.

Fig. 15 is a close up on Fig. 14 showing the solder stripes, the alignment tapers and the metal pads.

Fig. 16 shows the same as Fig. 15 after melting the solder stripes.

Fig. 17 A and B shows arrays of alignment tapers with photonic devices.

Fig. 18 shows an array of alignment tapers with photonic devices on a substrate also holding other features.

Fig. 19 shows an alternative embodiment of the tapered alignment features of the present invention.

Fig. 20A and B are top and cross sectional views of how an efficient sealing may be provided to an assembly structure according to the present invention.

The fabrication of the structures to be applied in hybrid integration procedures according to the present invention makes use of standard semiconductor technology. The invention can be realised in a plurality of embodiments of which only a representative selection is described here.

In a first embodiment the present invention relates to an assembly structure for performing hybridisation of an opto-electronic device onto a substrate holding a waveguide. An opto-electronic device can be a light emitting component such as a laser or a Light Emitting Diode (LED), or a light receiving component such as a photodiode. The hybrid integration includes aligning the laser and the waveguide, and soldering the laser to the substrate securing a long term mechanical stability.

The description of this first embodiment also serves as a general description of the essential features involved in the present invention. Therefore not all steps and features included in this description are necessary in order for the invention to be realised, and the description should by no means be interpreted as limiting the scope of the invention. The composition of the assembly structure is best described by going through the stepwise manufacturing procedure with reference to Figures 2-13.

Fig. 2 shows the first step of fabricating the assembly structure, in which a bottom cladding layer 12 is deposited on a substrate 10. Preferably the substrate is composed of Silicon or other inorganic or organic substrate material; the bottom-cladding layer is SiO_2 or other materials different from the core material to be deposited later. For practical purposes, the shown structure is nominally divided into a first part (in the back) and a second part (front). Fig. 3, an etch stop 14 is deposited on the second part of the bottom cladding. Possible etch stop materials are polysilicon, Boron doped polysilicon, metals or other inorganic materials. The next step consists of covering the structure with a deposited layer 16 of core glass, typically Germanium doped SiO_2 or other materials different from the cladding material, as shown in Fig. 4.

The depositing of cladding, etch stop and core glass layers can be carried out using Plasma Enhanced Chemical Vapour Deposition (PECVD), Low Pressure Chemical Vapour Deposition (LPCVD), or some vacuum deposition technique.

In Fig. 5, the formation of the waveguide core and alignment taper templates is carried out by a photolithographic process. First, the core glass layer is deposited onto the Si wafer. Next, the waveguide core and alignment taper templates are defined in the resist in the same photoresist processing step. The following RIE process removes the surrounding core glass material, leaving only the waveguide core 18 and the alignment taper templates 19. It is in this step that the essential horizontal alignment takes place. Since the waveguide core and the alignment taper templates are defined simultaneously in one mask step, the precision of the horizontal alignment is very precisely defined.

When working with optics in general, one often takes precautions to avoid back-scattering from surfaces such as input/output facets. The photolithography mask step described above provides a simple measure for doing this in the present invention. By changing the illumination mask, the end of the waveguide core can be defined having an angled termination, hence any reflection from this surface will leave the system.

The polysilicon etch stop 14 not covered by the alignment taper templates are removed by wet- or dry etching, exposing the bottom cladding layer, see Fig. 6. The waveguide core has to be covered by a material for it to be able to guide electromagnetic radiation. There exist several choices of materials for embedding the waveguide core for it to be able to

guide electromagnetic radiation. These can be defined using parameters such as refractive index. This is done in Fig. 7 where a top cladding layer 13, preferably similar to the bottom cladding layer, is deposited on the structure of Fig. 6. This cladding layer is removed again in an RIE process, but only from the second part of the structure, resulting in the structure in Fig. 8.

Completion of the etching process in Fig. 9 forms the alignment tapers 20 in the bottom cladding 12. Going from fig. 8 to 9, the etch stop mask 15 is also removed, revealing the top surface of the alignment tapers. It is important to note that the top surface of the bottom cladding layer 12 forms both the top surface of the alignment tapers and the surface on which the waveguide core 18 is deposited, that is, these are in the same plane. Thereby a very precise vertical alignment can be achieved by placing the object to be aligned on top of the alignment tapers.

A number of metal pads 22 are deposited on the exposed part of the silicon substrate 10 next to the alignment tapers 20 as shown in Fig. 10. These metal pads serve as wetable regions for binding solder to the substrate in a later soldering (see e.g. Fig 16). After this soldering, the pads also serve as both thermal paths to the silicon substrate, and as electrical contacts for the opto-electronic device. The depositing of the metals can be carried out by electroplating or vacuum deposition techniques.

As can be seen from Fig. 10, the whole assembly structure 30 is deposited on the substrate 10, and therefore no etching of trenches and groves in the silicon wafer is needed.

Referring now to Fig. 11, the opto-electronic device 24, a semiconductor laser in the preferred embodiment, is presented upside down showing the active region 28 to be aligned with the waveguide. The active region preferably resides so as to have its optical axis elevated above the bottom surface of the laser a distance equal to the distance of the optical axis of the waveguide above the bottom cladding layer. The exact position of the active region will be commented on later.

The laser 24 also holds one or more alignment features, here in the form of one or more solder stripes 26, which are deposited symmetrically on the bottom surface of the laser, with the active region 28 in the centre. One alignment step with the active region of the

laser as reference will be needed in depositing the solder stripes, the accuracy of which is typically 0.2µm. Electroplated stripes of AuSn80 having very smooth surface structures is the preferable solder material in the present invention. Semiconductor lasers are often fragile and need a very gentle handling. Since the solder stripes are "add-on" there is no need for etching the laser, which is considered a major advantage.

To perform the alignment, the laser 24 is flipped according to the arrow in Fig. 11, for the solder stripes 26 to fit the alignment tapers 20. Thereafter the laser is slid towards the first part of the assembly structure, until the solder stripes abut the alignment tapers, as is achieved in Fig. 12. This last action is where the alignment with the waveguide takes place and the tapering of the alignment tapers 20 guides or interlocks the laser 24 so that the active region 28 is aligned with the waveguide core 18. The laser now rests upon the alignment tapers which ensures the vertical alignment (note the vertical position of the active region described above), and the solder stripes clamps the alignment tapers ensuring the horizontal alignment. Thus both vertical and horizontal alignment has been achieved, and due to the clamping of the solder stripes to the alignment tapers, they are held together firmly without being inseparable.

The horizontal alignment is only sensitive to the relative alignment of the solder stripes 26 to the active region 28. As long as the solder stripes are positioned symmetrically, any amendments of their separation will change the gap between the laser and the waveguide, but not result in lateral misalignment. In Fig. 12, the aligned and assembled structure is shown while melting the solder stripes for fastening the opto-electronic device. Fig. 13 shows an exploded view of the structure of Fig. 12 revealing the melted solder stripes.

The alignment and fastening procedure performed in Figures 11 to 13 are described in detail referring to Figures 14 to 16. Figure 14 shows a front view of Fig. 12 where it is seen that the solder stripes 26 position the active region 28 precisely between the alignment tapers 20. From the close-up in Fig. 15 it is seen that the solder stripes contributes solely to the horizontal alignment, and therefore the height of the solder stripes is only restricted by the height of the alignment tapers. It is with noting that the alignment is performed prior to fastening of the opto-electronic device, hence any errors or inaccuracies obstructing a perfect alignment can be detected, and the fastening rejected.

After alignment, the melting of the solder stripes 26 effected from Fig. 15 to 16 is carried out by heating the assembled structure. In Fig. 16, the solder bulges up, wets, and excess solder flows along the metal pads 22 to make both thermal and electrical contact to the silicon substrate 10. This contact enables power supply to the laser 24 and enhances its temperature stability since it is over a broad area. Making additional wire bonding to the laser will heat the assembly considerably, however, since the laser rests on top of the alignment tapers, softening of the solder does not present a problem.

In the description of the assembly structure above (Fig. 11), it was implied that the active region 28 was residing a certain height above the bottom surface of the laser 24. However, in specific opto-electronic devices, the region to be aligned with the waveguide resides some given height above the bottom surface, inside the device, not being equal to the height of the centre of the waveguide core. This will cause the region 28 to be either elevated or lowered relative to the waveguide centre, when the device is mounted.

Two embodiments of the present invention addresses this problem, a first applies where the active region is elevated relative to the waveguide core centre, and a second when it is lowered.

First embodiment: The waveguide core 18 can be elevated by depositing a second cladding layer prior to formation of the core layer (16 in Fig. 4) by vacuum deposition. Instead of resting on the top surface of the bottom cladding layer, the waveguide core 18 in Fig 5 now rests on the remaining part of the second cladding layer, resting on the bottom cladding layer 12. This will elevate the waveguide a distance equal to the thickness of the second cladding layer above the top surface of the bottom cladding layer. Referring now to Figure 9, the top surface of the alignment taper 20 will still be in the plane of the top surface of the bottom cladding layer 12. Since the thickness of the second cladding layer is known, the top surface of the alignment tapers 20 is still well defined relative to the waveguide.

Second embodiment: The mounted device can be elevated relative to the waveguide by increasing the height of the alignment tapers. This is easily done by leaving all or part of the etch stop mask 15 in Fig. 8 otherwise removed after the etching of the cladding layers.

Adjusting the original thickness of the etch stop layer allows the mounted device to be elevated a given height relative to the waveguide.

These two well-defined height adjustments using only the thickness of a single layer, permits a precise vertical alignment of the waveguide and the opto-electronic device, also when the region to be aligned resides some given height above the bottom surface, i.e. inside the opto-electronic device.

Alternative embodiments of the present invention exist when the object is to align several photonic devices either relative to each other, or relative to another object. Here, a photonic device refers to both opto-electronic components and other optical devices such as amplifying waveguides. In this case there may not be a waveguide in the assembly structure. The alignment tapers will be positioned in either of two ways, as described in Figures 17 and 18:

1. a number of alignment tapers 20 defined in one mask step, and formed in the same cladding layer with the top surfaces of all tapers being in the same plane (Fig. 17 A and B), or
2. a number of alignment tapers 20 defined and formed as in 1, but the one mask step including the definition of another feature 32 on the substrate (Fig. 18). This other feature could be a photonic device or another alignment feature.

The embodiment addressed in Fig 17A applies where two or more photonic devices are hybrid integrated after each other in a line. Contrary to the waveguide in the assembly structure described above, none of the photonic devices to be aligned are formed on the substrate. The two or more photonic devices 25 have light input/output ports, which are to be internally aligned in order to acquire an efficient light coupling between them.

In the embodiments shown in Figures 17B and 18 the alignment tapers and the attached device(s), are oriented relative to an imaginary frame of reference. The alignment will be both an alignment and a three-dimensional positioning with a high precision in especially the transverse directions relative to the alignment tapers.

These two embodiments can be utilised when e.g. an array of photonic devices is desired. The array of alignment tapers can be formed as described in 1 above (Fig 17B), on a

separate substrate 11, which thereby holds an array of internally aligned devices 25. Or, as described in 2 (Fig. 18), the array can be formed and internally aligned on a substrate holding other features such as 32, the array being aligned relative to these features also. The procedure of forming the alignment tapers and attaching the device are essentially the same as in the embodiment described in with reference to Figures 2 through 13.

The one or more tapered alignment features according to the present invention may have different shapes. In an alternative embodiment, a tapered alignment feature is formed which provide the tapered side surface parts as inner side surface parts as illustrated in Figure 19. Here, an assembly structure is formed on a substrate 10 holding a waveguide 18 and the tapered alignment feature 42. In order to improve the precision of the assembly, the waveguide 18 and the tapered alignment feature 42 are preferably defined in a single mask step. Also, the top surface of the tapered alignment feature 42 is preferably in the same plane as the bottom-cladding layer holding the waveguide 18. The active region 28 of an optoelectronic device 25 can be vertically aligned with the waveguide 18 by positioning the optoelectronic device 25 on top of the alignment feature 42. Second alignment features, such as solder stripes 48, positioned symmetrically around the active region 28 are formed on the lower surface of the optoelectronic device 25. The active region 28 will be horizontally aligned with the waveguide 18 when the optoelectronic device 25 is moved towards the waveguide 18 until the solder stripes 48 abut the tapered side surface parts of the alignment feature 42. In order to fix and provide electrical connections to the optoelectronic device 25, the solder stripes can be melted forming a binding electrical connection to a metallized region 44. Alternatively, the second alignment features can be formed by other structures than solder stripes 48, such as one or more silica structures. In this case, the fixation and the electrical connection can be formed by a solder stripe 50 forming a binding electrical connection to a metallized region 46.

The principles of the present invention provide a precise method for positioning and aligning devices and structures at different positions on a substrate. Several 3-dimensional positioning and alignment arrangements of photonic devices are feasible by combining any of the above described embodiments. Also, hybrid integration, involving alignment and positioning, is of interest for numerous classes of photonic devices, which further extends the scope of the present invention.

The assembly structure of the present invention also provides an assembly which is well suited for sealing the one or more optoelectronic devices on the assembly structure.

Figure 20 shows an application example where the processing steps for forming of the glass waveguides and the alignment features are integrated with the necessary processing steps for forming a hermetic solder seal around the optoelectronic device for protection.

Figure 20A shows a top view of an assembly structure according to a preferred embodiment of the present invention. In parallel with the formation of the waveguide 18, a glass ring 32 is formed surrounding the mounted optoelectronic device 25 and the light input/output end of the waveguide 18. The glass ring 32 can be formed using the same processing steps, masks and materials, which was used to form the assembly structure. The upper part of the glass ring 32 holds metallized areas 35 and a solder seal ring 37 as can be seen on the cross sectional view of Figure 20B. The glass ring 32 intersects seamlessly with the bottom and top cladding layers 31 and 52 of the waveguide structure and with a pedestal 36. A lid 40 can be soldered to the assembly structure by positioning the lid 40 on top of the assembly structure so as to make contact between the solder seal ring 37 and metallized areas 35 on the lid 40. Applying heat to the assembly will fix the lid 40 to and seal the device. The lid 40 preferably consists of silicon.

The lower surface of the glass ring 32 on the pedestal 36 encompasses electrically conductive feedthroughs 39 which preferably consist of highly doped polysilicon. The feedthroughs are connected to metallized areas 35 which is interconnected by a wire or ribbon bond 33. Metallized areas 35 together with bonds 33 and feedthroughs 39 forms electrical connections from the outside of the sealing to the sealed optoelectronic device as can be seen on Figure 20A. Alternatively, the electrical connections can be formed by vertical feedthroughs 41, which electrically connect top and bottom surface of the substrate 10.

As mentioned in the above, the necessary structuring for providing the sealing can be included in the processing steps used to form the waveguide and alignment features.

The structuring of the pedestal 36 and lower parts of the glass ring 32 is formed in the same processing steps and mask as the structuring of the waveguide bottom-cladding

layer 31 and the alignment tapers 34 (Similar to the steps described in relation to Figures 5 and 9). Also, the structuring of the polysilicon feedthroughs 39 can be done in the same process step described in relation to Figure 6. Similarly, the metallized areas 35 can be formed in the process step used to form the metallized areas 22 described in relation to Figure 10.

The solder seal ring 37 can be applied to the metallized glass ridge 32 as shown in Figure 20B, but it can also be applied to metallized areas 35 the lid 40. The solder seal ring 37 consists preferably of an alloy with a lower melting point than the solder alloy used for mounting the semiconductor devices onto the first surface.

CLAIMS

1. An assembly structure comprising:

- a substrate holding a bottom cladding layer, said bottom cladding layer comprising a first and a second part, wherein each part comprises a top and a bottom surface separated by a distance d,

- an optical waveguide comprising a top and a bottom surface and a light receiving input end, said optical waveguide defining a first optical axis, the bottom surface of said optical waveguide being positioned at a distance larger than or equal to d above the bottom surface of the bottom cladding layer,

- one or more first alignment features being formed in the second part of the bottom cladding layer, said first alignment features having a top surface which is essentially in the same plane as the top surface of the first part of the bottom cladding layer, said one or more first alignment features further comprising a first and a second tapered side surface part in directions at least substantially parallel to the first optical axis, and

- a top cladding layer surrounding the optical waveguide so as to guide electromagnetic radiation within the optical waveguide.

2. An assembly structure according to claim 1 further comprising a set of electrical contact pads.

3. An assembly structure according to claim 1 or 2, wherein the bottom surface of the optical waveguide is positioned on the top surface of the bottom cladding layer at a distance substantially equal to d above the bottom surface of the bottom cladding layer.

4. An assembly structure according to any of the preceding claims, further comprising

- an optoelectronic device comprising an active part and a light output port, said output port being optically aligned with the waveguide input by having the optoelectronic device arranged on top of the first alignment features to thereby obtain vertical alignment between the light receiving input end of the optical waveguide with the light output port of the optoelectronic device.

5. An assembly structure according to claim 4, wherein the optoelectronic device further comprises one or more second alignment features, and wherein one or more of said second alignment features abut the first and second tapered side surface parts of the first alignment features so as to horizontally align the light receiving input end of the optical waveguide with the light output port of the optoelectronic device.

6. An assembly structure according to any of claims 1-3 further comprising

- an optoelectronic device comprising a light output port, an active part and one or more second alignment features, wherein one or more of the second alignment features abut the first and second tapered side surface parts of the first alignment features so as to align the light receiving input end of the optical waveguide with the light output port of the optoelectronic device.

7. An assembly structure according to any of claims 4-6, wherein the active part of the optoelectronic device defines a second optical axis which is at least substantially coincident with the first optical axis.

8. An assembly structure according to any of claims 4-7, wherein an etch stop layer is provided on top of the first alignment features below the optoelectronic device.

9. An assembly structure according to any of claims 1-8, wherein, during the formation of said assembly, the positioning of the optical waveguide and the first alignment features are defined using a single mask.

10. An assembly structure according to any of claims 1-9, wherein two of the first alignment features provides the tapered side surface parts, said two alignment

features being separated by a distance larger than the width of the active part of the optoelectronic device.

11. An assembly structure according to any of claims 5-10, wherein the second alignment features comprise solder stripes arranged on the bottom of the optoelectronic device so as to at least partly engage outer side walls of the first alignment features.

12. An assembly structure according to claim 11, wherein at least two solder stripes are arranged on the bottom of the optoelectronic device.

13. An assembly structure according to any of claims 4-12, wherein the optoelectronic device is soldered to contact pads formed on exposed parts of the substrate.

14. An assembly structure according to any of claims 4-13, wherein the optoelectronic device comprises a semiconductor laser diode.

15. An assembly structure according to any of claims 4-13, wherein the optoelectronic device comprises an LED or a photodiode.

16. An assembly structure according to any of claims 4-6, wherein the substrate holds a ridge at least partly encircling the optoelectronic device, the assembly structure further comprising a lid soldered to said ridge for sealing the optoelectronic device and the input end of the waveguide.

17. A method of forming an assembly structure for assembling an optoelectronic device and an optical waveguide, said optical waveguide comprising a light input end for receiving light emitted from an output port of the optoelectronic device, said method comprising the steps of:

- providing a bottom cladding layer on top of a substrate, said bottom cladding layer comprising a first and a second part, wherein each part comprises a top and a bottom surface separated by a distance d,

- providing a core layer on top of at least part of the bottom cladding layer,

- forming the optical waveguide in the core layer, said optical waveguide thereby extending along a first optical axis in a plane and at a distance larger than or equal to d from the bottom surface of the first part of the bottom cladding layer, and

- forming one or more first alignment features in the second part of the bottom cladding layer so that at least one top surface of the first alignment features is in essentially the same plane as the top surface of the first part of the bottom cladding layer, the step of forming the one or more first alignment features comprises the step of forming a first and a second tapered side surface part in directions at least substantially parallel to the first optical axis.

18. A method according to claim 17, further comprising

- aligning the output port of the optoelectronic device with the light input end of optical waveguide, said alignment comprising the step of arranging the optoelectronic device on top of the one or more alignment features so as to obtain vertical alignment.

19. A method according to claim 17 or 18, wherein the optical waveguide extends on the top surface of the bottom cladding layer at a distance substantially equal to d above the bottom surface of the bottom cladding layer.

20. A method according to claim 18 or 19, wherein the optoelectronic device further comprises one or more second alignment features, and wherein the step of aligning the output port of the optoelectronic device with the light input end of optical waveguide further comprises the step of abutting said second alignment features to the first and second tapered side surface parts of the first alignment features so as to obtain horizontal alignment.

21. A method according to any of claims17-20, wherein the positioning of the optical waveguide and the first alignment features is defined using a single mask.

22. A method according to any of the claims 18-21, wherein an etch stop layer is provided on top of the first alignment features below the optoelectronic device.

23. A method according to any of claims 17-22, wherein

- an etch stop layer is provided on at least part of the second part of the bottom cladding layer prior to deposition of the core layer, said core layer extending on both the first and the second part of the bottom cladding layer thereby covering at least part of the etch stop layer, and

the formation of the optical waveguide and the first alignment features comprises:

a) defining the horizontal configuration of the optical waveguide and the first alignment features in the core layer by a single mask process,

b) partially removing the core layer thereby forming the optical waveguide and defining the first alignment features in the core layer,

c) removing that part of the etch stop layer not being covered by the core layer,

d) providing a top cladding layer so as to at least partly cover the optical waveguide and optionally the one or more alignment features formed in the core layer, and

e) removing the top cladding layer, the core layer and at least part of the second part of the bottom cladding layer to thereby form the first alignment features in the bottom cladding layer.

24. A method according to claim 23 and any of claims 17-21, further comprising the step of:

- removing the etch stop layer defining the one or more alignment features formed in the bottom cladding layer.

25. A method according to claim 23, wherein the removing in step e) comprises etching the second part of the bottom cladding layer so as to expose that part of the substrate not being covered by the first alignment features.

26. A method according to any of claims 23-25, wherein step e) comprises etching by reactive ion etching.

27. A method according to any of claims 17-26, wherein one or more second alignment features are arranged on the bottom of the optoelectronic device so as to at least partly engage outer side walls of the first alignment features when aligning the optoelectronic device.

28. A method according to claim 27, wherein the second alignment features comprise solder stripes.

29. A method according to claim 28, wherein at least two solder stripes are arranged on the bottom of the optoelectronic device.

30. A method according to any of claims 18-29, further comprising soldering the optoelectronic device to one or more electrical contact pads formed beside the alignment features on exposed parts of the substrate.

31. A method according to any of claims 17-30, wherein the optoelectronic device comprises a a semiconductor laser diode.

32. A method according to any of claims 17-30, wherein the optoelectronic device comprises an LED or photodiode.

33. A method according to any of claims 17-32, further comprising the steps of:

forming, on the substrate, a ridge at least partly encircling the optoelectronic device,

providing a lid, and

soldering said lid to said ridge for sealing the optoelectronic device and the input end of the waveguide.

34. An assembly structure comprising:

- a substrate having one or more first alignment features disposed thereon, and

- a first photonic device having a light input or output port for receiving or emitting light along a first optical axis, and having a bottom surface having one or more second alignment features disposed thereon,

the assembly structure being characterised in that:

the one or more first or second alignment features form a first and a second side surface part which are tapered in directions at least substantially parallel to the first optical axis, and

the first photonic device is positioned on top of at least one of the one or more first alignment features, whereby two or more surface parts of the one or more first alignment features abuts two or more surface parts of the one or more second alignment features, the abutting surface parts comprising the first and second side surface parts.

35. An assembly structure according to claim 34, further comprising

- a second photonic device comprising a light input or output port for receiving or emitting light along a second optical axis, and comprising a bottom surface having one or more second alignment features disposed thereon, wherein

the one or more first or second alignment features provides a third and fourth side surface part which are tapered in directions at least substantially parallel to the second optical axis, and

the second photonic device is positioned on top of at least one of the one or more first alignment features, whereby two or more surface parts of the one or more first alignment features abuts two or more surface parts of the one or more second alignment features, the abutting surface parts comprising the third and fourth side surface parts.

36. An assembly structure according to claim 34 or 35, wherein the light input or output port of a photonic device has a predetermined orientation and height with respect to the substrate.

37. An assembly structure according to claim 35 or 36, wherein the first photonic device comprises a light input port and the second photonic device comprises a light output port, and wherein the photonic devices are positioned so as to align the light input port of the first photonic device with the light output port of the second photonic device.

38. An assembly structure according to claim 35 or 36, wherein the first photonic device and the second photonic device both have a light output port, and the photonic devices are positioned so as to align the two light output ports along two at least substantially parallel optical paths.

39. An assembly structure according to claim 35 or 36, wherein the first optical axis and the second optical axis are at least substantially parallel.

40. An assembly structure according to any of claims 34-39, wherein the second alignment features of the first and/or second photonic device comprise one or more solder stripes.

41. An assembly structure according to claim 40, wherein at least two solder stripes are arranged on the bottom of a photonic device.

42. An assembly structure according to any of claims 35-41, wherein the height of the one or more first alignment features is adjusted so as to obtain vertical alignment.

43. An assembly structure according to any of claims 34-42, wherein a photonic device comprises a passive optical component, such as an optical waveguide, such as an optical fibre or a planar waveguide.

44. An assembly structure according to any of claims 34-43, wherein a photonic device comprises an optoelectronic device, such as a laser diode, an LED or a photodiode.

45. An assembly structure according to any of claims 34-44, wherein a photonic device comprises an active waveguide component, such as an optical amplifier, such as a fibre amplifier.

46. A method of forming an assembly structure, said method comprising the steps of:

- providing a substrate having one or more first alignment features disposed thereon,

- providing a first photonic device having a light input or output port for receiving or emitting light along a first optical axis, and having a bottom surface having one or more second alignment features disposed thereon, wherein

the one or more first or second alignment features form a first and a second side surface part which are tapered in directions at least substantially parallel to the first optical axis,

the method further comprising the step of:

- positioning the first photonic device on top of at least one of the one or more first alignment features, whereby two or more surface parts of the one or more first

alignment features abuts two or more surface parts of the one or more second alignment features, the abutting surface parts comprising the first and second side surface parts.

47. A method according to claim 46, further comprising the step of:

- providing a second photonic device comprising a light input or output port for receiving or emitting light along a second optical axis, and comprising a bottom surface having one or more second alignment features disposed thereon, wherein

the one or more first or second alignment features provides a third and fourth side surface part which are tapered in directions at least substantially parallel to the second optical axis, and

the method further comprising the step of:

- positioning the second photonic device on top of at least one of the one or more first alignment features, whereby two or more surface parts of the one or more first alignment features abuts two or more surface parts of the one or more second alignment features, the abutting surface parts comprising the third and fourth side surface parts.

48. A method according to claim 46 or 47, wherein the light input or output port of a photonic device has a predetermined orientation and height with respect to the substrate.

49. A method according to claim 47 or 48, wherein the first photonic device comprises a light input port and the second photonic device comprises a light output port, and the photonic devices are positioned so as to align the light input port of the first photonic device with the light output port of the second photonic device.

50. A method according to claim 47 or 48, wherein the first photonic device and the second photonic device both have a light output port, and wherein the photonic

devices are positioned so as to align the two light output ports along two at least substantially parallel optical paths.

51. A method according to claim 47 or 48, wherein the photonic devices are positioned so as to make the first optical axis and the second optical axis at least substantially parallel.

52. A method according to any of claims 46-51, wherein the second alignment features of the first and/or second photonic device comprise one or more solder stripes.

53. A method according to claim 52, wherein at least two solder stripes are arranged on the bottom of a photonic device.

54. A method according to any of claims 46-53, wherein the height of the first alignment features is adjusted so as to obtain vertical alignment.

55. A method according to any of claims 46-54, wherein the engagement of the first alignment features and the second alignment features ensures horizontal alignment.

56. A method according to any of claims 46-55 wherein a photonic device comprises a passive optical component, such as an optical waveguide, such as an optical fibre or a planar waveguide.

57. A method according to any of claims 46-55, wherein a photonic device comprises an optoelectronic device, such as a laser diode, an LED or a photodiode.

58. A method according to any of claims 46-55, wherein a photonic device comprises an active waveguide component, such as an optical amplifier, such as a fibre amplifier.

59. An assembled structure comprising a first, lower structure part and a second, upper structure part, wherein:

- the first structure part comprises:

  - a first substrate, an upper surface of which defines a first plane, the substrate comprising a first and a second part
  - a first radiation guiding, emitting, and/or receiving means positioned on or above the first part of the first substrate and in a fixed relation thereto, the means defining a first optical axis extending at least substantially parallel to the first plane,
  - one or more first alignment elements positioned on or above the second part of the first substrate, the one or more first alignment elements having one or more upper surface parts being in a fixed relationship to the first optical axis and the first plane, and the one or more first alignment elements having one or more side surface parts being positioned in a predefined position in relation to the first optical axis,

- the second structure part comprises:

  - a second substrate having a lower surface defining a second plane being at least substantially parallel to the first plane,
  - a second means for guiding, emitting, and/or receiving radiation, the means defining a second optical axis and being positioned below the second substrate and in a fixed relation thereto,
  - one or more second alignment elements positioned below the second substrate, and the one or more second alignment elements having one or more side surface parts being positioned in a predefined position in relation to the second optical axis,

the second structure part having one or more lower surface parts being in a fixed relationship to the second optical axis and the second plane,

the one or more first and second alignment elements being relatively positioned so that, when the first and second optical axes are at least substantially coincident:

- at least part of the one or more upper surface parts of the one or more first alignment elements abut at least part of the one or more lower surface parts of the second structure part,
- at least part of the one or more side surface parts of the one or more first alignment elements abut at least part of the one or more side surface parts of the one or more second alignment elements, and
- the abutting side surface parts of at least one of the one or more first and second alignment elements comprising at least two surface parts extending in different planes, at angles different from 0 and 90 degrees from the first optical axis.

60. An assembly according to claim 59, wherein the abutting side surface parts and upper and lower surface parts are positioned so as to, when projected perpendicularly onto the first plane, reside within an area within the first plane, the area being defined as the overlap between the first and second parts when these are projected perpendicularly onto the first plane.

61. An assembly structure according to claim 59 or 60, wherein the first and second structure parts each further comprises a set of electrical contact pads positioned so as to abut or engage and thereby provide electrical contact between the contact pads of the first and second parts.

62. An assembly structure according to any of claims 59 to 61, wherein the second alignment elements comprise at least one, such as at least two, solder stripes.

63. An assembly structure according to claim 62, wherein the first structure element comprises at least one contact pad positioned so as to abut or engage the at least one solder stripe of the second part.

64. An assembly structure according to claim 63, wherein the first and second parts are fixedly interconnected at least in part by an engagement, such as a soldering, between the solder stripe(s) and contact pad(s).

65. An assembly structure according to any of claims 59 to 64, wherein the radiation guiding, emitting, and/or receiving means of at least one of the first and second structure parts comprises:

- a waveguide, such as an optical fibre or a planar waveguide, where the optical axis is defined by a longitudinal axis of the waveguide,
- a light emitter, such as a semiconductor laser diode or an LED, and where the optical axis is defined as an axis of symmetry of radiation emitted by the light emitter, and/or
- an active waveguide component, such as an optical amplifier, such as a fibre amplifier, where the optical axis is defined by a longitudinal axis of the waveguide.

66. An assembly structure according to any of claims 59 to 65, where, in the first structure part, the one or more upper surface parts define a plane at least substantially comprising a lower side of the first means for guiding, emitting and/or receiving radiation.

67. An assembly structure according to any of claims 59 to 66, wherein the abutting side surface parts of one of the first and the second structure part define an inwardly or outwardly tapered part, viewed from the respective means for guiding, emitting, and/or receiving radiation.

68. An assembly structure according to claim 67, wherein, in one or both of the first and second structure part, the one or more alignment elements are positioned so as to provide a space at least corresponding to a cross section of an active part of the means for guiding, emitting, and/or receiving radiation, the cross section being translated along the respective optical axis over the second part of the respective structure part.

69. A first structure part for use in the assembled structure according to any of claims 59 to 68.

70. A second structure part for use in the assembled structure according to any of claims 59 to 68.

71. A method of manufacturing a first structure part for use in the assembled structure according to any of claims 59 to 68, the method comprising:

1. providing a substrate having a first and a second part,

2. providing a means for guiding, emitting, and/or receiving light, the means defining an optical axis, the means being positioned on or above the first part of the substrate and so as to be fixed in relation to the substrate and so that the optical axis is in a predetermined relation to the substrate,

3. providing one or more alignment elements on or above the substrate, the one or more alignment elements being positioned:
   - on or above the second part of the substrate,
   - so that the one or more alignment element has/have one or more upper surface parts being in a fixed relationship to the first optical axis and the first plane, and
   - so that the one or more first alignment element has/have one or more side surface parts being positioned in a predefined position in relation to the first optical axis.

72. A method according to claim 71, wherein steps 2) and 3) comprise the steps of:

I. providing a first layer of a first material on or over at least substantially all of an upper surface of the first and second parts of the substrate, the first material having a first effective refractive index,

II. providing a second layer of a second material on at least substantially all of an upper surface of the first layer and at least over or at the first part of the substrate, the second material having a second effective refractive index being different from the first effective refractive index, and

III. removing a predetermined part of the second layer.

73. A method according to claim 72, wherein steps 2) comprises providing between steps I) and II), a third layer of a third material on the upper surface of the first layer and at least over or at the second part of the substrate, the third material being adapted to withstand a process of removing at least part of the first layer.

74. A method according to claim 73, wherein:

- step II) comprises providing the second layer also on the third layer,

- step III) comprises the steps:

  a) predefining the parts, both over or at the first and second parts of the substrate, of the second layer which should be removed,
  b) removing the predefined parts of the second layer.

75. A method according to claim 74, wherein step 2) comprises providing, at least over or at the first part of the substrate, a fourth layer of a fourth material on the structure resulting after step b), the fourth material having a refractive index being different from the second refractive index.

76. A method according to claim 74 or 75, wherein step III) further comprises removing those parts of the third layer on which predefined parts of the second layer are positioned.

77. A method according to claim 76, wherein step 3) further comprises removing all remaining parts of the second layer on or above the second part of the substrate.

78. A method according to claim 76 or 77, wherein step 2) further comprising removing at least substantially all parts of the first layer, which parts correspond to parts of the third layer removed during step b).

79. A method according to any of claims 74 to 77, wherein step III) further comprises removing at least substantially all remaining parts of the third layer above or at the second part of the substrate.

80. A method according to claim 74, wherein step a) comprises predefining the parts in a single step, preferably using a lithographic process and by using a single mask.

81. A method according to claim 7, wherein:

the further removing step of step 3) is performed using a predefined removal procedure, such as an etching procedure, such as reactive ion etching, and wherein

step II) comprises providing a third layer of a third material, such as an etch stop, which is adapted to not be removed during the predefined removal step.

82. A method of assembling an assembled structure according to any of claims 59 to 68, the method comprising:

- providing the first and second structural parts,
- positioning the first and second structural parts in order to form the assembly, and
- fixing the first and second structural parts to each other.

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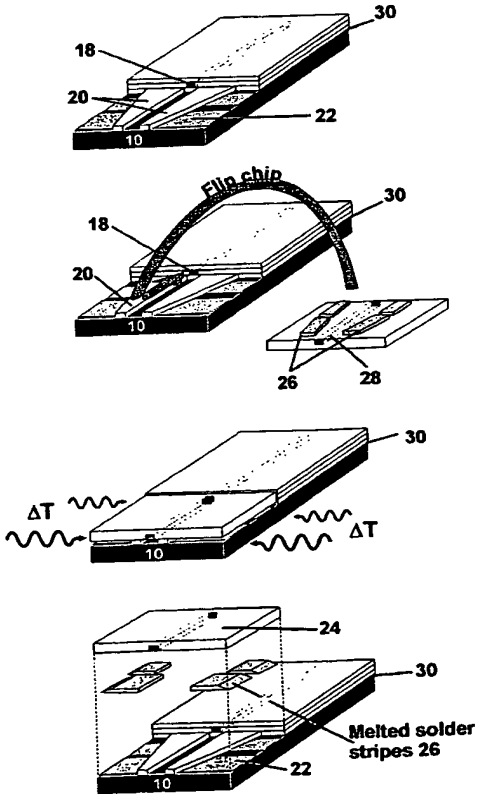
(54) Title: HYBRID INTEGRATION OF ACTIVE AND PASSIVE OPTICAL COMPONENTS ON AN SI-BOARD



(57) Abstract: The present invention relates to an assembly structure and a method for assembling active and passive photonic and/or optoelectronic devices on a silicon board. The invention relates in particular to an assembly structure and a method for aligning the photonic devices during the assembling procedure. According to the present invention, the assembly structure comprises one or more alignment features comprising tapered side surface parts in directions at least substantially parallel to an optical axis. By providing a tapering in a direction at least substantially parallel to the first optical axis, any inaccuracies primarily affects the non-critical positioning in the direction along the optical axis, whereas the critical positioning transverse to the optical axis merely depends on the symmetry of alignment features. The errors from the inherent inaccuracy of the position and shape of alignment features are thereby minimised. Also, the devices to be aligned are preferably arranged on top of the alignment features which forms part of the basic structure on the silicon board. All alignment features can thereby be defined in a single mask step together with the structures with which the alignment is to be carried out, resulting in an improved accuracy of the assembly structure. The resulting components will be used especially for broadband telecommunication components.

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CLAIMS

1. An assembly structure comprising:

- a substrate holding a bottom cladding layer, said bottom cladding layer comprising a first and a second part, wherein each part comprises a top and a bottom surface separated by a distance d,

- an optical waveguide comprising a top and a bottom surface and a light receiving input end, said optical waveguide defining a first optical axis, the bottom surface of said optical waveguide being positioned at a distance larger than or equal to d above the bottom surface of the bottom cladding layer,

- one or more first alignment features being formed in the second part of the bottom cladding layer, said first alignment features having a top surface which is essentially in the same plane as the top surface of the first part of the bottom cladding layer, said one or more first alignment features further comprising a first and a second tapered side surface part in directions at least substantially parallel to the first optical axis, and

- a top cladding layer surrounding the optical waveguide so as to guide electromagnetic radiation within the optical waveguide.

2. An assembly structure according to claim 1 further comprising a set of electrical contact pads.

3. An assembly structure according to claim 1 or 2, wherein the bottom surface of the optical waveguide is positioned on the top surface of the bottom cladding layer at a distance substantially equal to d above the bottom surface of the bottom cladding layer.

4. An assembly structure according to any of the preceding claims, further comprising

- an optoelectronic device comprising an active part and a light output port, said output port being optically aligned with the waveguide input by having the optoelectronic device arranged on top of the first alignment features to thereby obtain vertical alignment between the light receiving input end of the optical waveguide with the light output port of the optoelectronic device.

5. An assembly structure according to claim 4, wherein the optoelectronic device further comprises one or more second alignment features, and wherein one or more of said second alignment features abut the first and second tapered side surface parts of the first alignment features so as to horizontally align the light receiving input end of the optical waveguide with the light output port of the optoelectronic device.

6. An assembly structure according to any of claims 1-3 further comprising

- an optoelectronic device comprising a light output port, an active part and one or more second alignment features, wherein one or more of the second alignment features abut the first and second tapered side surface parts of the first alignment features so as to align the light receiving input end of the optical waveguide with the light output port of the optoelectronic device.

7. An assembly structure according to any of claims 4-6, wherein the active part of the optoelectronic device defines a second optical axis which is at least substantially coincident with the first optical axis.

8. An assembly structure according to any of claims 4-7, wherein an etch stop layer is provided on top of the first alignment features below the optoelectronic device.

9. An assembly structure according to any of claims 1-8, wherein, during the formation of said assembly, the positioning of the optical waveguide and the first alignment features are defined using a single mask.

10. An assembly structure according to any of claims 1-9, wherein two of the first alignment features provides the tapered side surface parts, said two alignment

features being separated by a distance larger than the width of the active part of the optoelectronic device.

11. An assembly structure according to any of claims 5-10, wherein the second alignment features comprise solder stripes arranged on the bottom of the optoelectronic device so as to at least partly engage outer side walls of the first alignment features.

12. An assembly structure according to claim 11, wherein at least two solder stripes are arranged on the bottom of the optoelectronic device.

13. An assembly structure according to any of claims 4-12, wherein the optoelectronic device is soldered to contact pads formed on exposed parts of the substrate.

14. An assembly structure according to any of claims 4-13, wherein the optoelectronic device comprises a semiconductor laser diode.

15. An assembly structure according to any of claims 4-13, wherein the optoelectronic device comprises an LED or a photodiode.

16. An assembly structure according to any of claims 4-6, wherein the substrate holds a ridge at least partly encircling the optoelectronic device, the assembly structure further comprising a lid soldered to said ridge for sealing the optoelectronic device and the input end of the waveguide.

17. A method of forming an assembly structure for assembling an optoelectronic device and an optical waveguide, said optical waveguide comprising a light input end for receiving light emitted from an output port of the optoelectronic device, said method comprising the steps of:

- providing a bottom cladding layer on top of a substrate, said bottom cladding layer comprising a first and a second part, wherein each part comprises a top and a bottom surface separated by a distance d,

- providing a core layer on top of at least part of the bottom cladding layer,

- forming the optical waveguide in the core layer, said optical waveguide thereby extending along a first optical axis in a plane and at a distance larger than or equal to d from the bottom surface of the first part of the bottom cladding layer, and

- forming one or more first alignment features in the second part of the bottom cladding layer so that at least one top surface of the first alignment features is in essentially the same plane as the top surface of the first part of the bottom cladding layer, the step of forming the one or more first alignment features comprises the step of forming a first and a second tapered side surface part in directions at least substantially parallel to the first optical axis.

18. A method according to claim 17, further comprising

- aligning the output port of the optoelectronic device with the light input end of optical waveguide, said alignment comprising the step of arranging the optoelectronic device on top of the one or more alignment features so as to obtain vertical alignment.

19. A method according to claim 17 or 18, wherein the optical waveguide extends on the top surface of the bottom cladding layer at a distance substantially equal to d above the bottom surface of the bottom cladding layer.

20. A method according to claim 18 or 19, wherein the optoelectronic device further comprises one or more second alignment features, and wherein the step of aligning the output port of the optoelectronic device with the light input end of optical waveguide further comprises the step of abutting said second alignment features to the first and second tapered side surface parts of the first alignment features so as to obtain horizontal alignment.

21. A method according to any of claims17-20, wherein the positioning of the optical waveguide and the first alignment features is defined using a single mask.

22. A method according to any of the claims 18-21, wherein an etch stop layer is provided on top of the first alignment features below the optoelectronic device.

23. A method according to any of claims 17-22, wherein

- an etch stop layer is provided on at least part of the second part of the bottom cladding layer prior to deposition of the core layer, said core layer extending on both the first and the second part of the bottom cladding layer thereby covering at least part of the etch stop layer, and

the formation of the optical waveguide and the first alignment features comprises:

a) defining the horizontal configuration of the optical waveguide and the first alignment features in the core layer by a single mask process,

b) partially removing the core layer thereby forming the optical waveguide and defining the first alignment features in the core layer,

c) removing that part of the etch stop layer not being covered by the core layer,

d) providing a top cladding layer so as to at least partly cover the optical waveguide and optionally the one or more alignment features formed in the core layer, and

e) removing the top cladding layer, the core layer and at least part of the second part of the bottom cladding layer to thereby form the first alignment features in the bottom cladding layer.

24. A method according to claim 23 and any of claims 17-21, further comprising the step of:

- removing the etch stop layer defining the one or more alignment features formed in the bottom cladding layer.

25. A method according to claim 23, wherein the removing in step e) comprises etching the second part of the bottom cladding layer so as to expose that part of the substrate not being covered by the first alignment features.

26. A method according to any of claims 23-25, wherein step e) comprises etching by reactive ion etching.

27. A method according to any of claims 17-26, wherein one or more second alignment features are arranged on the bottom of the optoelectronic device so as to at least partly engage outer side walls of the first alignment features when aligning the optoelectronic device.

28. A method according to claim 27, wherein the second alignment features comprise solder stripes.

29. A method according to claim 28, wherein at least two solder stripes are arranged on the bottom of the optoelectronic device.

30. A method according to any of claims 18-29, further comprising soldering the optoelectronic device to one or more electrical contact pads formed beside the alignment features on exposed parts of the substrate.

31. A method according to any of claims 17-30, wherein the optoelectronic device comprises a a semiconductor laser diode.

32. A method according to any of claims 17-30, wherein the optoelectronic device comprises an LED or photodiode.

33. A method according to any of claims 17-32, further comprising the steps of:

forming, on the substrate, a ridge at least partly encircling the optoelectronic device,

providing a lid, and

soldering said lid to said ridge for sealing the optoelectronic device and the input end of the waveguide.

34. An assembly structure comprising:

- a substrate having one or more first alignment features disposed thereon, and

- a first photonic device having a light input or output port for receiving or emitting light along a first optical axis, and having a bottom surface having one or more second alignment features disposed thereon,

the assembly structure being characterised in that:

the one or more first or second alignment features form a first and a second side surface part which are tapered in directions at least substantially parallel to the first optical axis, and

the first photonic device is positioned on top of at least one of the one or more first alignment features, whereby two or more surface parts of the one or more first alignment features abuts two or more surface parts of the one or more second alignment features, the abutting surface parts comprising the first and second side surface parts.

35. An assembly structure according to claim 34, further comprising

- a second photonic device comprising a light input or output port for receiving or emitting light along a second optical axis, and comprising a bottom surface having one or more second alignment features disposed thereon, wherein

the one or more first or second alignment features provides a third and fourth side surface part which are tapered in directions at least substantially parallel to the second optical axis, and

the second photonic device is positioned on top of at least one of the one or more first alignment features, whereby two or more surface parts of the one or more first alignment features abuts two or more surface parts of the one or more second alignment features, the abutting surface parts comprising the third and fourth side surface parts.

36. An assembly structure according to claim 34 or 35, wherein the light input or output port of a photonic device has a predetermined orientation and height with respect to the substrate.

37. An assembly structure according to claim 35 or 36, wherein the first photonic device comprises a light input port and the second photonic device comprises a light output port, and wherein the photonic devices are positioned so as to align the light input port of the first photonic device with the light output port of the second photonic device.

38. An assembly structure according to claim 35 or 36, wherein the first photonic device and the second photonic device both have a light output port, and the photonic devices are positioned so as to align the two light output ports along two at least substantially parallel optical paths.

39. An assembly structure according to claim 35 or 36, wherein the first optical axis and the second optical axis are at least substantially parallel.

40. An assembly structure according to any of claims 34-39, wherein the second alignment features of the first and/or second photonic device comprise one or more solder stripes.

41. An assembly structure according to claim 40, wherein at least two solder stripes are arranged on the bottom of a photonic device.

42. An assembly structure according to any of claims 35-41, wherein the height of the one or more first alignment features is adjusted so as to obtain vertical alignment.

43. An assembly structure according to any of claims 34-42, wherein a photonic device comprises a passive optical component, such as an optical waveguide, such as an optical fibre or a planar waveguide.

44. An assembly structure according to any of claims 34-43, wherein a photonic device comprises an optoelectronic device, such as a laser diode, an LED or a photodiode.

45. An assembly structure according to any of claims 34-44, wherein a photonic device comprises an active waveguide component, such as an optical amplifier, such as a fibre amplifier.

46. A method of forming an assembly structure, said method comprising the steps of:

- providing a substrate having one or more first alignment features disposed thereon,

- providing a first photonic device having a light input or output port for receiving or emitting light along a first optical axis, and having a bottom surface having one or more second alignment features disposed thereon, wherein

the one or more first or second alignment features form a first and a second side surface part which are tapered in directions at least substantially parallel to the first optical axis,

the method further comprising the step of:

- positioning the first photonic device on top of at least one of the one or more first alignment features, whereby two or more surface parts of the one or more first

alignment features abuts two or more surface parts of the one or more second alignment features, the abutting surface parts comprising the first and second side surface parts.

47. A method according to claim 46, further comprising the step of:

- providing a second photonic device comprising a light input or output port for receiving or emitting light along a second optical axis, and comprising a bottom surface having one or more second alignment features disposed thereon, wherein

the one or more first or second alignment features provides a third and fourth side surface part which are tapered in directions at least substantially parallel to the second optical axis, and

the method further comprising the step of:

- positioning the second photonic device on top of at least one of the one or more first alignment features, whereby two or more surface parts of the one or more first alignment features abuts two or more surface parts of the one or more second alignment features, the abutting surface parts comprising the third and fourth side surface parts.

48. A method according to claim 46 or 47, wherein the light input or output port of a photonic device has a predetermined orientation and height with respect to the substrate.

49. A method according to claim 47 or 48, wherein the first photonic device comprises a light input port and the second photonic device comprises a light output port, and the photonic devices are positioned so as to align the light input port of the first photonic device with the light output port of the second photonic device.

50. A method according to claim 47 or 48, wherein the first photonic device and the second photonic device both have a light output port, and wherein the photonic

devices are positioned so as to align the two light output ports along two at least substantially parallel optical paths.

51. A method according to claim 47 or 48, wherein the photonic devices are positioned so as to make the first optical axis and the second optical axis at least substantially parallel.

52. A method according to any of claims 46-51, wherein the second alignment features of the first and/or second photonic device comprise one or more solder stripes.

53. A method according to claim 52, wherein at least two solder stripes are arranged on the bottom of a photonic device.

54. A method according to any of claims 46-53, wherein the height of the first alignment features is adjusted so as to obtain vertical alignment.

55. A method according to any of claims 46-54, wherein the engagement of the first alignment features and the second alignment features ensures horizontal alignment.

56. A method according to any of claims 46-55 wherein a photonic device comprises a passive optical component, such as an optical waveguide, such as an optical fibre or a planar waveguide.

57. A method according to any of claims 46-55, wherein a photonic device comprises an optoelectronic device, such as a laser diode, an LED or a photodiode.

58. A method according to any of claims 46-55, wherein a photonic device comprises an active waveguide component, such as an optical amplifier, such as a fibre amplifier.

59. An assembled structure comprising a first, lower structure part and a second, upper structure part, wherein:

- the first structure part comprises:

  - a first substrate, an upper surface of which defines a first plane, the substrate comprising a first and a second part
  - a first radiation guiding, emitting, and/or receiving means positioned on or above the first part of the first substrate and in a fixed relation thereto, the means defining a first optical axis extending at least substantially parallel to the first plane,
  - one or more first alignment elements positioned on or above the second part of the first substrate, the one or more first alignment elements having one or more upper surface parts being in a fixed relationship to the first optical axis and the first plane, and the one or more first alignment elements having one or more side surface parts being positioned in a predefined position in relation to the first optical axis,

- the second structure part comprises:

  - a second substrate having a lower surface defining a second plane being at least substantially parallel to the first plane,
  - a second means for guiding, emitting, and/or receiving radiation, the means defining a second optical axis and being positioned below the second substrate and in a fixed relation thereto,
  - one or more second alignment elements positioned below the second substrate, and the one or more second alignment elements having one or more side surface parts being positioned in a predefined position in relation to the second optical axis,

the second structure part having one or more lower surface parts being in a fixed relationship to the second optical axis and the second plane,

the one or more first and second alignment elements being relatively positioned so that, when the first and second optical axes are at least substantially coincident:

- at least part of the one or more upper surface parts of the one or more first alignment elements abut at least part of the one or more lower surface parts of the second structure part,
- at least part of the one or more side surface parts of the one or more first alignment elements abut at least part of the one or more side surface parts of the one or more second alignment elements, and
- the abutting side surface parts of at least one of the one or more first and second alignment elements comprising at least two surface parts extending in different planes, at angles different from 0 and 90 degrees from the first optical axis.

60. An assembly according to claim 59, wherein the abutting side surface parts and upper and lower surface parts are positioned so as to, when projected perpendicularly onto the first plane, reside within an area within the first plane, the area being defined as the overlap between the first and second parts when these are projected perpendicularly onto the first plane.

61. An assembly structure according to claim 59 or 60, wherein the first and second structure parts each further comprises a set of electrical contact pads positioned so as to abut or engage and thereby provide electrical contact between the contact pads of the first and second parts.

62. An assembly structure according to any of claims 59 to 61, wherein the second alignment elements comprise at least one, such as at least two, solder stripes.

63. An assembly structure according to claim 62, wherein the first structure element comprises at least one contact pad positioned so as to abut or engage the at least one solder stripe of the second part.

64. An assembly structure according to claim 63, wherein the first and second parts are fixedly interconnected at least in part by an engagement, such as a soldering, between the solder stripe(s) and contact pad(s).

65. An assembly structure according to any of claims 59 to 64, wherein the radiation guiding, emitting, and/or receiving means of at least one of the first and second structure parts comprises:

- a waveguide, such as an optical fibre or a planar waveguide, where the optical axis is defined by a longitudinal axis of the waveguide,
- a light emitter, such as a semiconductor laser diode or an LED, and where the optical axis is defined as an axis of symmetry of radiation emitted by the light emitter, and/or
- an active waveguide component, such as an optical amplifier, such as a fibre amplifier, where the optical axis is defined by a longitudinal axis of the waveguide.

66. An assembly structure according to any of claims 59 to 65, where, in the first structure part, the one or more upper surface parts define a plane at least substantially comprising a lower side of the first means for guiding, emitting and/or receiving radiation.

67. An assembly structure according to any of claims 59 to 66, wherein the abutting side surface parts of one of the first and the second structure part define an inwardly or outwardly tapered part, viewed from the respective means for guiding, emitting, and/or receiving radiation.

68. An assembly structure according to claim 67, wherein, in one or both of the first and second structure part, the one or more alignment elements are positioned so as to provide a space at least corresponding to a cross section of an active part of the means for guiding, emitting, and/or receiving radiation, the cross section being translated along the respective optical axis over the second part of the respective structure part.

69. A first structure part for use in the assembled structure according to any of claims 59 to 68.

70. A second structure part for use in the assembled structure according to any of claims 59 to 68.

71. A method of manufacturing a first structure part for use in the assembled structure according to any of claims 59 to 68, the method comprising:

1. providing a substrate having a first and a second part,

2. providing a means for guiding, emitting, and/or receiving light, the means defining an optical axis, the means being positioned on or above the first part of the substrate and so as to be fixed in relation to the substrate and so that the optical axis is in a predetermined relation to the substrate,

3. providing one or more alignment elements on or above the substrate, the one or more alignment elements being positioned:
   - on or above the second part of the substrate,
   - so that the one or more alignment element has/have one or more upper surface parts being in a fixed relationship to the first optical axis and the first plane, and
   - so that the one or more first alignment element has/have one or more side surface parts being positioned in a predefined position in relation to the first optical axis.

72. A method according to claim 71, wherein steps 2) and 3) comprise the steps of:

I. providing a first layer of a first material on or over at least substantially all of an upper surface of the first and second parts of the substrate, the first material having a first effective refractive index,

II. providing a second layer of a second material on at least substantially all of an upper surface of the first layer and at least over or at the first part of the substrate, the second material having a second effective refractive index being different from the first effective refractive index, and

III. removing a predetermined part of the second layer.

73. A method according to claim 72, wherein steps 2) comprises providing between steps I) and II), a third layer of a third material on the upper surface of the first layer and at least over or at the second part of the substrate, the third material being adapted to withstand a process of removing at least part of the first layer.

74. A method according to claim 73, wherein:

- step II) comprises providing the second layer also on the third layer,

- step III) comprises the steps:

  a) predefining the parts, both over or at the first and second parts of the substrate, of the second layer which should be removed,
  b) removing the predefined parts of the second layer.

75. A method according to claim 74, wherein step 2) comprises providing, at least over or at the first part of the substrate, a fourth layer of a fourth material on the structure resulting after step b), the fourth material having a refractive index being different from the second refractive index.

76. A method according to claim 74 or 75, wherein step III) further comprises removing those parts of the third layer on which predefined parts of the second layer are positioned.

77. A method according to claim 76, wherein step 3) further comprises removing all remaining parts of the second layer on or above the second part of the substrate.

78. A method according to claim 76 or 77, wherein step 2) further comprising removing at least substantially all parts of the first layer, which parts correspond to parts of the third layer removed during step b).

79. A method according to any of claims 74 to 77, wherein step III) further comprises removing at least substantially all remaining parts of the third layer above or at the second part of the substrate.

80. A method according to claim 74, wherein step a) comprises predefining the parts in a single step, preferably using a lithographic process and by using a single mask.

81. A method according to claim 7, wherein:

the further removing step of step 3) is performed using a predefined removal procedure, such as an etching procedure, such as reactive ion etching, and wherein

step II) comprises providing a third layer of a third material, such as an etch stop, which is adapted to not be removed during the predefined removal step.

82. A method of assembling an assembled structure according to any of claims 59 to 68, the method comprising:

- providing the first and second structural parts,
- positioning the first and second structural parts in order to form the assembly, and
- fixing the first and second structural parts to each other.

PATENT COOPERATION TREATY

PLOUGMANN VINGTOFT & PARTNERS

26 OKT. 2001

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

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P.O. Box 3007
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DANEMARK

PCT

CLI/AK

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT
(PCT Rule 71.1)

Date of mailing *(day/month/year)*	24.10.2001
Applicant's or agent's file reference: 23339 PC 1	**IMPORTANT NOTIFICATION**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/DK00/00407	17/07/2000	16/07/1999

Applicant
HYBRID MICRO TECHNOLOGIES ApS

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/	Authorized officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	De Caevel, J-M Tel.+49 89 2399-2251

Form PCT/IPEA/416 (July 1992)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
23339 PC 1		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/DK00/00407	17/07/2000	16/07/1999
International Patent Classification (IPC) or national classification and IPC G02B6/10		
Applicant HYBRID MICRO TECHNOLOGIES ApS		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 9 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 4 sheets (document D6) sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
14/02/2001	24.10.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Elflein, W Telephone No. +49 89 2399 2820

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/DK00/00407

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

Description, pages:

1-32 as originally filed

Claims, No.:

1-9 as received on 26/09/2001 with letter of 26/09/2001

Drawings, sheets:

1/9-9/9 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☒ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)
see separate sheet

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-9
	No:	Claims	
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1-9
Industrial applicability (IA)	Yes:	Claims	1-9
	No:	Claims	

2. Citations and explanations
see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

1 The following documents are referred to in this report:
D1 = US 5 488 678 A (MOTOTAKA TANEYA ET AL) 30 January 1996,
D4 = EP 0807838 A,
D6 = JP 7198973 A and translation.
The documents D4 and D6 are cited by the examiner (Art.33(6)). A copy of the document D6 is annexed to the communication.

Re Item I

Basis of the report

1. Paragraph c. in **claim 1** specifies a step of "removing parts ... not defined in step a." that extends beyond the content of the application as originally filed (see in particular the original claim 23,"removing that parts ... not defined in step a."), where the omission of the word "that" introduces the possibility that "other" parts not defined in step a. are not removed (Art.34(2)b).

2. The features of present **claim 7** relate to an embodiment (original independent claim 46 and its dependent claims) that is different from the embodiment of present claim 1 (original claim 17 and its dependent claims). Therefore, the features of present claim 7 has not been disclosed in combination (Art.34(2)b).

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. I. Concerning claim 1, D4 discloses (in the Figures and corresponding text) a method of forming an assembly structure (see Fig.2A) adapted to assembling and aligning an optoelectronic device (7) and an optical waveguide (5 Fig.3E), said optical waveguide comprising a light input (5 in Fig.1A) end for receiving light emitted from an output port of the optoelectronic device, said method comprising the steps of:
   i. providing a bottom cladding layer (2 in Fig.3A) on top of a substrate, said bottom cladding layer comprising a first and a second part (6 in Fig.3B), wherein each part comprises a top and a bottom surface separated by a distance d (thickness of the bottom cladding layer),
   ii. providing an etch stop layer (6b in Fig.3B) on part of the second part of the bottom cladding layer,

iii. providing a core layer (5 in Fig.3C) on top of the bottom cladding layer, said core layer extending on both the first and the second part of the bottom cladding layer thereby covering at least part of the each stop layer, and

iv. forming an optical waveguide (5 in Fig.3E) and one or more first alignment features (6b and the underlaying "bump") on the assembly structure by:

v. defining parts of the core layer for forming an optical waveguide core (leading to the core 5 shown in Fig.D.),

vi. removing parts of the core layer not defined in step v), thereby forming the optical waveguide core (5 in Fig.d.) in the core layer, said optical waveguide thereby extending along a first optical axis in a plane and at a distance larger than or equal to d from the first bottom surface of the first part of the bottom cladding layer,

vii. providing a top cladding layer (4 in Fig.d.) so as to at least partly cover the optical waveguide core, and

viii. etching into the structure over the second part of the bottom cladding layer to remove the top cladding layer and that parts of the second part of the bottom cladding layer not covered by the etch stop layer (the result of this step is shown in Fig.3E), thereby forming the first alignment features (6b and underlaying "bump") in the second part of the bottom cladding layer so that least one top surface of the first alignment features is in essentially the same plane as the top surface of the first part of the bottom cladding layer.

II. The method of claim 1 mainly differs from the method of D4 in that

a. the first alignment features comprise a first and a second tapered side surface part in directions substantially parallel to the first optical axis.

Claim 1 further differs form the D4 in that

b. a single mask process is used to define, parts of the core layer for forming an optical waveguide core and for defining a horizontal configuration of the first alignment features, and

c. removing parts of the core layer not defined in step a), thereby forming

the optical waveguide core in the core layer and defining the horizontal configuration of the first alignment features in the core layer,

d. providing a top cladding layer covering the parts of the core layer providing the horizontal configuration of the first alignment features,

e. etching into the structure over the second part of the bottom cladding layer to remove the core layer,

f. removing that parts of the etch stop layer not covered by the core layer.

III. The first alignment features of D4 provide automatic alignment of the waveguide and the optoelectronic device in the vertical direction only, and the horizontal alignment must be carried out in an active manner (see col.8, lines 39-47), which is a difficult process.

D1 discloses an method of aligning an optoelectronic device (100 in Fig.3F) with an optical waveguide (155, see col. 19, lines 31-34, "this raised structure defines the waveguide"), wherein

a. a first alignment feature (162 in Fig.3E) comprises a first and a second tapered side surface part in directions substantially parallel to the first optical axis (see waveguide ridge 155),

This method simplifies the alignment of the optoelectronic device in the horizontal direction.

In order to simplify the alignment of the waveguide and the optoelectronic device in the horizontal direction, a skilled person could be expected to shape the first alignment feature of D4 according the teaching of D1, thereby arriving at feature a.

IV. In D1, the horizontal configuration of the waveguide and the alignment features must be formed so that their center lines are aligned horizontally and they are processed simultaneously (see col.7, lines 39-45), but it does not specify which processing step should be simultaneous. Simultaneous single-mask processes are common in the art, and are known for providing precise horizonal alignment. The skilled person would therefore understand this text passage as referring to a single mask process for forming the waveguide and the alignment feature. Furthermore, single-mask

manufacturing processes are simpler than processes with several masks.

V. Single mask processes can be applied to any planar structures, such as the substrate in Fig.3C of D4. In order to simplify the manufacturing process of the assembly structure of D4, a skilled person would consider using a single mask process for forming the waveguide (5 in Fig.d., see also col.6, lines 46-47). When carrying out this modified method, the horizontal configuration of the first alignment features will be formed in the core layer automatically (feature b).

VI. When carrying out step v., the horizontal configuration of the alignment features would be defined in the core layer automatically (feature c).
In D1, that parts of all layers not covered by the core layer are removed. In order to improve the precision of the process of D4, the skilled person would remove that parts of all layers not covered by the core layer, including the etch stop layer (feature f).
In step vii, the top cladding layer (4) would also cover the parts of the core layer providing the horizontal configuration of the first alignment features automatically (feature d).
In step viii, the core layer over the second part of the bottom cladding layer would be removed automatically (feature e).

VII. The modified method would have steps a. to f. in addition to steps i.-viii., and would therefore correspond to the method claimed in **claim 1**, which therefore is not inventive (Art.33(3)).

VIII. For the sake of completeness, it is indicated that the method of D1 leads to precise horizontal alignment, and the method of D4 leads to vertical alignment. The indicated combination of these methods would lead to the method of claim 1, providing horizontal and vertical alignment.

2. In D4, the optical waveguide extends on the top of the bottom cladding layer at a distance substantially equal to d above the bottom surface of the bottom cladding layer, so **claim 2** is not inventive (Art.33(3)).

3. In D1, all the layers on top of the alignment feature (162 in Fig.3F) are removed, leading to an adjustment of the height of the optoelectronic device. If an adjustment of the position of the optoelectronic device of D4 was desired, a skilled person could be expected to remove all the layers on top of the alignment feature, including the etch stop layer. By this modification, the skilled person would arrive at **claim 3** (Art.33(3)).

4. In D4, the optoelectronic device is arranged on top of the alignment features so as to obtain vertical alignment of the output port of the optoelectronic device with the light input end of the optical waveguide (see the abstract). **Claim 4** is therefore not inventive (Art.33(3)).

5. The optoelectronic device of D1 comprises a second alignment feature (221 in Fig.4 or 120 in Fig.3A) which abuts the first and second tapered side surface parts of the first alignment features so as to horizontally align the light receiving input end of the optical waveguide with the light output port of the optoelectronic device (see col.10, lines 60-68 and col.8, line 39), so **claim 5** does not relate to inventive matter (Art. 33(3)).

6. The step of removing the etch step in D4 comprises etching by reactive ion etching (see col.7, line 31), so **claim 6** is not inventive (Art.33(3)).

7. As regards claim 7, see "ITEM I" above.

8. In D1 (see Fig.9A-9C, and col.25-26), an optoelectronic device is soldered to electrical contact pads (764) formed beside alignment features (761) on parts of the substrate. In order to establish electrical contact to the optoelectronic device (100 in Fig.3F) of D4, a skilled person could be expected to recognise that the soldered contacts of Fig.9A to 9C could advantageously be used on the exposed parts of the substrate (150). Such a modification would lead to **claim 8**, which therefore is not inventive (Art.33(3)).

9. D6 discloses a method of sealing an assembly structure comprising the steps of:
   - forming, on the substrate, a ridge (11) at least partly encircling the optoelectronic device (4, 5),

- providing a lid (6), and
- soldering said lid to said ridge (see paragraph 18) for sealing the optoelectronic device and the input end of the waveguide.

In order to seal the assembly structure of D4, a skilled person would consider using the method of D6, thereby arriving at **claim 9** (Art.33(3))

Re Item VII

Certain defects in the international application

The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

PATENT COOPERATION TREATY

From the:
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:
PLOUGHMANN, VINGTOFT & PARTNERS A/S
Sankt Ann Plads 11
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DANEMARK

PLOUGMANN VINGTOFT & PARTNERS
29 AUG. 2001

PCT

WRITTEN OPINION

(PCT Rule 66)

Date of mailing *(day/month/year)*	13.08.2001
Applicant's or agent's file reference: 23339 PC 1	**REPLY DUE** **within 1 month(s)** from the above date of mailing

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/DK00/00407	17/07/2000	16/07/1999

International Patent Classification (IPC) or both national classification and IPC
G02B6/10

Applicant
HYBRID MICRO TECHNOLOGIES ApS

1. This written opinion is the **first** drawn up by this International Preliminary Examining Authority.

2. This opinion contains indications relating to the following items:

I	☒	Basis of the opinion
II	☐	Priority
III	☐	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
IV	☐	Lack of unity of invention
V	☒	Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
VI	☐	Certain document cited
VII	☒	Certain defects in the international application
VIII	☒	Certain observations on the international application

3. The applicant is hereby **invited to reply** to this opinion.

When? See the time limit indicated above. The applicant may, before the expiration of that time limit, request this Authority to grant an extension, see Rule 66.2(d).

How? By submitting a written reply, accompanied, where appropriate, by amendments, according to Rule 66.3. For the form and the language of the amendments, see Rules 66.8 and 66.9.

Also: For an additional opportunity to submit amendments, see Rule 66.4. For the examiner's obligation to consider amendments and/or arguments, see Rule 66.4 bis. For an informal communication with the examiner, see Rule 66.6.

If no reply is filed, the international preliminary examination report will be established on the basis of this opinion.

4. The final date by which the international preliminary examination report must be established according to Rule 69.2 is: 16/11/2001.

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I. Basis of the opinion

1. With regard to the **elements** of the international application (Replacement *sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this opinion as "originally filed".)*:

Description, pages:

1-32 as originally filed

Claims, No.:

1-82 as originally filed

Drawings, sheets:

1/9-9/9 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	34-39, 46-51, 55, 59-60, 65-75, 80-82
Inventive step (IS)	Claims	1-10, 13-15, 17-22, 27-32, 40-45, 52-54, 56-58, 61-64, 79
Industrial applicability (IA)	Claims	

2. Citations and explanations
see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

1 The following documents are referred to in this communication:

D1 = US 5 488 678 A (MOTOTAKA TANEYA ET AL) 30 January 1996,
D2 = US 5745631,
D3 = EP 0 864 893 A2 (NIPPON TELEGRAPH AND TELEPHONE CORPORATION) 16 September 1998,
D4 = EP 0807838 A,
D5 = MASATAKA ITOH et al.: 'Use of AuSn solder bumps in three-dimensional passive aligned packaging of LD/PD arrays on Si optical benches', IEEE ELECTRONIC COMPONENTS AND TECHNOLOGY CONFERENCE, 1996, pages 1 to 7.

(D2, D4 and D5 are cited by the examiner, and D5 is also cited in the description. Copies of these documents are annexed to the communication.)

SECTION V:

1 I. Having regard to **claim 1**, D1 discloses an assembly structure (see Fig.4 and corresponding text) comprising:

a. a substrate (251) supporting a bottom cladding layer (252), said bottom cladding layer comprising a first and a second part (280 and 260 respectively),

b. an optical waveguide (254, see also 155 in Fig.3D) comprising a top and a bottom surface and a light receiving input end, said optical waveguide defining a first optical axis (290), the bottom surface of said optical waveguide being positioned at a distance larger than or equal to the thickness of the bottom cladding layer above the bottom surface of the bottom cladding layer,

c. one or more first alignment features being formed in the second part of the bottom cladding layer, said one or more first alignment features further comprising a first and a second tapered side surface part in directions at least substantially parallel to the first optical axis, and

d. a top cladding layer surrounding the optical waveguide so as to guide electromagnetic radiation within the optical waveguide.

However, claim 1 additionally specifies that

e. each of the parts of the bottom layer comprises a top and a bottom surface separated by a distance d (lines 1-3 of the claim), and that

f. said first alignment features have a top surface which is essentially in the same plane as the top surface of the first part of the bottom cladding layer (lines 15-17 of the claim).

II. However, document D4 discloses (in Fig.3A to 3E) an assembly structure having a substrate (1) holding a bottom cladding layer (2) with a first and a second part (6 in Fig.3B), where the alignment features in the second part are etched using etch stops (6b), so that a good control of the layer thickness of the alignment features is achieved (see col.4, line 48 to 57). The assembly structure of D4 therefore has features e. and f (see also bottom cladding layer 10 in Fig.5 or Fig.6B).

In order to improve the control of the layer thickness of the alignment feature, a skilled person could be expected to etch the alignment features of D1 using the etch stop layer taught in D4, thereby automatically arriving at an assembly structure having features e and f in addition to features a to d, so claim 1 does not appear to be inventive (Art. 33(3)).

2 The assembly structure of D1 has electrical contact pads (it has a Au/Zn layer, see col.8, line 16, for bonding to electrode 109, see col.6, lines 53-57; see also sets of contact pads 704 and 764 in Fig.9A-9C), so **claim 2** does not appear to be inventive as well (Art. 33(3)).

3 We now turn to **claim 3**. In D4, the lower bottom cladding layer (2) has a thickness d of 6 micrometers, on top of which a 1 micrometer thick second bottom cladding layer (3) is provided, and an optical waveguide (5) extends on the top surface of the bottom cladding layer (2, 3). D4 teaches that the thickness of the second bottom cladding layer (3) has to be adapted so as to result in a predetermined overall bottom layer thickness (see col.6, lines 19-28). So in order to enable efficient butt coupling efficiency of the waveguide to a laser diode mounted on top of the first alignment features, a skilled person could be expected to make the upper bottom cladding layer (3) as thin as necessary, and, clearly, certain diode constructions would result in a waveguide that extends at a distance substantially

equal to d above the bottom surface of the bottom cladding layer (2, 3). Thus, claim 3 does not appear inventive (Art. 33(3)).
An similar argument applies also to **claim 19** (Art.33(3))

4 D1 has an optoelectronic device (100) comprising an active part (103) and a light output port (111, see col.6), the output port being optically aligned with the waveguide input by having the optoelectronic device arranged on top of the first alignment features to thereby obtain vertical alignment between the light receiving input end of the optical waveguide with the light output port of the optoelectronic device ("butt-coupling" see col.9, lines 17-28). The subject-matter of **claim 4** does not therefore appear to be inventive (Art. 33(3)).
A similar argument applies to **claim 18.**

5 The optoelectronic device of D1 comprises a second alignment feature (221 or 120) which abuts the first and second tapered side surface parts of the first alignment features so as to horizontally align the light receiving input end of the optical waveguide with the light output port of the optoelectronic device (see col.10, lines 60-68 and col.8, line 39), so **claim 5** does not relate to inventive matter (Art. 33(3)).
A similar objection applies to **claim 20.**

6 The optoelectronic device of D1 comprises a light output port (111, see col.6, line 18), an active part (103) and a second alignment feature (120 or 221), wherein the second alignment feature abut the first and second tapered side surface parts of the first alignment features so as to align the light receiving input end of the optical waveguide with the light output port of the optoelectronic device (see col.10, lines 60-68, or col.8, line 39). So **claim 6** does not appear to be inventive (Art. 33(3)).

7 The active part of the optoelectronic device of D1 defines a second optical axis (130 in Fig.3B) which is at least substantially coincident with the first optical axis (so that butt coupling is achieved, see col.10, line 67). Therefore **Claim 7** also does not appear to be inventive (Art. 33(3)).

8 In the assembly structure referred to in point 1 above, an etch stop layer (6b in Fig.2B of D4) is provided on top of the first alignment features below the

optoelectronic device (7 in D4), so **claim 8** does not appear to involve an inventive step (Art.33 (3)).

9 **Claim 9** refers to a fabrication method step using a single mask; but this method step is in a claim relating to an apparatus, and claim 9 is unclear since an apparatus fabricated using this method step can apparently not be distinguished from an apparatus fabricated without using this method step. Moreover, the use of such a single mask would not appear to be inventive, since a skilled person would normally try to use the least number of masks (Art.6 and Art. 33(3)).

10 D1 discloses two "first" alignment features (362 in Fig.5) that provide tapered side surface parts that are separated by a distance larger than the width of the active part of the optoelectronic device, so **claim 10** does not appear to be inventive (Art. 33(3)).

11 Claim 11 is understood as referring to second alignment features that comprise solder stripes arranged on the bottom of the optoelectronic device adapted to clamp the outer side walls of the alignment features (see also p.27). **Claim 11** and dependent **claim 12** would not appear to be rendered obvious by the prior art presently available.

12 Soldering an optoelectronic device to contact pads in an assembly structure is well known in the art (e.g. Fig. 9A of D1 shows contact pads 704 and 764, that are soldered together in Fig.9B) and thereby facilitates the fabrication of electrical connections to the optoelectronic device. Thus **claim 13** does not appear to be inventive (Art.33(3)).

13 The optoelectronic device of D1 comprises a semiconductor laser diode (see col. 5, line 56), so **claim 14** does not appear to be inventive (Art. 33(3)).
A similar objection applies to **claim 31**.

14 **Claim 15** does not appear to be inventive either, as D3 shows photodiodes in a similar assembly structure (Art. 33(3)).
A similar objection applies to **claim 32**.

15 **Claim 16 and 33 respectively** are not disclosed nor suggested in the available prior art documents.

16 Independent **claim 17** effectively specifies a method of forming an assembly structure having features a to c and e (see point 1 above) that are rendered obvious by D1 and D4.

However, claim 17 additionally specifies that the assembly structure

f. comprises an optoelectronic device and an optical waveguide comprising a light input end for receiving light emitted from an output port of the optoelectronic device, and

g. is formed by providing a core layer, in which an optical waveguide is formed.

But the assembly structure of D1 has features f (see col.10) and g (see col.7). So the combined teaching of D1 and D4 as alluded to above apparently renders obvious a method of forming an assembly structure (see e.g. col.6-8 in D1) having the above features a to c, e, f and g. Claim 17 therefore does not appear to be inventive (Art. 33(3)).

17 Concerning claims 18, 19 and 20, see points 4, 3 and 5 above, respectively.

18 In D1, the optical waveguide (155) and the first alignment features (162) are simultaneously defined, and they are mutually aligned in the horizontal direction (see col.7, lines 39-44). Processes using a single mask ("self-aligned process") are well known in the art, and provide precise horizontal alignment and a simple manufacturing process. In order to facilitate the formation of a precisely aligned assembly structure, a skilled person could be expected to use a single mask process for positioning the optical waveguide and the first alignment structures. **Claim 21** therefore does not appear to involve an inventive step (Art. 33(3)).

19 In the method referred to in point 17 above, an etch stop layer is provided on top of the first alignment features below the optoelectronic device. So **claim 22** does not appear to involve an inventive activity (Art. 33(3)).

20 **Claim 23** would not appear to be disclosed nor suggested in the prior art presently available. The dependency of **claim 24** is not clear. It is however imagined that

claim 24 is intended to refer to claim 23 when claim 23 depends on 17-21 (Art. 6). **Claim 25** is also not clear but it is understood as referring to the step of exposing "that part of the substrate not being covered by the first alignment features" as a result of the process step of claim 24 (Art. 6). Notwithstanding the clarity problems of claims 24 and 25, the subject-matter of **claims 24, 25 and 26** when dependent upon claim 23 would also not appear to be rendered obvious be the prior art presently available.

21 D1 anticipates the feature of **claim 27** (Art.33(3)).

22 D2 discloses solder bumps that are used as second alignment features by means of surface tension effects, and D5 teaches that solder stripes provide a better alignment precision than solder bumps (see e.g. Fig.12 and corresponding text on page 5). A skilled person, wishing to improve the alignment precision, could be expected to design the solder second alignment features of D2 in the form of stripes, so **claim 28** would not appear to be inventive (Art.33(3)).
Similar objections apply to **claims 40 and 62**.

23 The solder stripes referred to in point 22 above are arranged on the bottom of the optoelectric device. **Claim 29** does not therefore appear to involve an inventive activity (Art.33(3)).

24 In D1 (see Fig.9A-9C, and col.25-26), an optoelectronic device is soldered to electrical contact pads (764) formed beside alignment features (761) on parts of the substrate. In order to establish electrical contact to the optoelectric device (100) of Fig.3F, a skilled person could be expected to recognise that the soldered contacts of Fig.9A to 9C could advantageously be used on the exposed parts of the substrate (150) of Fig.3F. Such a modification would lead to the subject-matter of **claim 30**, which therefore does not appear to be inventive (Art.33(3)).

25 Concerning claims 31-33, see points 13-15 above.

26 Concerning **claim 34**, D3 discloses (in Fig.24 and corresponding text) an assembly structure comprising:

a. a substrate having first alignment features (33-10a, 33-10b) disposed

thereon, and

b. a first photonic device (31a) having a light input or output port for receiving or emitting light along a first optical axis, and having a bottom surface having one or more second alignment features disposed thereon (31-10a, 31-10b),

c. wherein the first or second alignment features form a first and a second side surface part which are tapered in a direction at least substantially parallel to the first optical axis, and

d. the first photonic device is positioned on top of at least one of the one or more first alignment features, whereby the surface parts of the one or more first alignment features abuts the surface parts of the one or more second alignment features, the abutting surface parts comprising the first and second side surface parts.

Therefore, **claim 34** is not new (Art.33(2)).

27 The dependent **claims 35-39** read onto the arrangement shown in Fig. 24 of D3 and are not new (Art.33(2)).

28 Concerning claim 40, see point 22 above.

29 D3 discloses the features of **claim 41** (Fig.18), **claim 42** (since optical coupling is achieved, see lines 1-2 of the abstract), **claim 43** (Fig.24), and **claim 44** (see Fig.7), which all therefore do not appear to be inventive (Art.33(3)). A similar argument to the one referring to claim 15 applies to **claim 45** (Art.33(3)).

30 **Claim 46** is a method equivalent to claim 34 and is open to a similar objection to the objection raised against claim 34 (Art.33(2)).

31 The features of the dependent **claims 47-51** are also apparently not new having regard to the device of Fig.24 of D3 (Art.33(2)).

32 Similar arguments to those presented with respect to claims 40, 41, 42, 43, 44 and 45 apply to **claims 52, 53, 54, 56, 57 and 58** (Art.33(3)) .

33 The feature of **claim 55** is evidently taught in D3 (see Fig.16 and p.24, lines 46-47, Art.33(2)).

34 Turning to independent claim 59, D1 discloses (in Fig.3A-3F, or Fig.4, and corresponding text) an assembled structure comprising :

a. a first, lower structure part (150) and a second, upper structure part (100), wherein

b. the first structure part (150) comprises:

c. a first substrate (151), an upper surface which defines a first plane (substrate surface), the substrate comprising a first and a second part (180 and 160 respectively),

d. a "first" radiation guiding means (155 and 153) positioned on or above the first part of the first substrate and, of course, in a fixed relation thereto, the means defining a first optical axis (190) extending parallel to the first plane,

e. a first alignment element (162) positioned on or above the second part of the first substrate, the first alignment element having an upper surface part that is in a fixed relationship to the first optical axis and the first plane, and the first alignment element has side surface parts being positioned in a predefined position in relation to the first optical axis (see Fig.3D to 3F), and wherein

f. the second structure part (100) comprises:

g. a second substrate having a lower surface (120) defining a second plane at least substantially parallel to the first plane (when the second structure part is mounted upside down, see Fig.3F),

h. a "second" means for emitting radiation (103), the means defining a second optical axis (130) positioned below the second substrate (see Fig.3F) and thereby in a fixed relation thereto,

i. one or more second alignment elements (120 in Fig.3A) positioned below the second substrate (see Fig.3F), the one or more second alignment elements having one or more side surface parts positioned in a predefined position in relation to the second optical axis,

j. the second structure part having one or more lower surface parts (120) that are in a fixed relationship to the second optical axis and the second plane,

k. the one or more first and second alignment elements being relative positioned so that the first and second optical axes are at least substantially

coincident ("butt-coupling", see col.10, last line), and

l. a part of the upper surface parts of the first alignment elements abut a part of the lower surface part of the second structure part ("contact", col.10, line 46),

m. a part of the side surface parts of the first alignment element abut a part of the side surface parts of the second alignment element (see col.12, lines 35-40), and

n. the abutting side surface parts of the first and second alignment elements comprise at least two surface parts extending in different planes, at angles that are different from 0 and 90 degrees from the first optical axis (see the Figures).

Therefore, **claim 59** is not new (Art. 33(2)).

35 The geometrical features referred to in dependent **claim 60**, are apparently also present in Fig.3F of D1 (Art. 33(2)).

36 Concerning **claim 61**, D2 discloses (in Fig.3-8) first and second structure parts (20, 32) each comprising a set of electrical contact pads (28, 34) positioned so as to abut and thereby provide electrical contact between the contact pads of the first and second parts (see col.3, last line).
D1 (see Fig.9A-9C) or D3 (see Fig.18A-18C) teaches similar contact pads.

In order to establish an electrical contact between the first and second structure part of Fig.3A-3F of D1, a skilled person could be expected to consider using electrical contact pads, so claim 61 would not appear to be inventive (Art.33(3)).

37 Concerning claim 62, see point 22 above.

38 The contact pads (34 in D2) of the first structure element referred to in point 37 are positioned (see Fig.8) so as to abut a solder stripe (see 28 in D2) of the second part, so **claim 63** would not appear to be inventive (Art.33(3)).

39 The first and second structure parts of D2 are fixedly interconnected by soldering between the solder stripes and the contact pads (see col.2, lines 10-12), so **claim 64** would not appear to be inventive (Art.33(3)).

40 **Claims 65, 66, 67** read on the assembly structure of D1 (Art.33(2)), and Fig.4 of D1 shows a geometric arrangement as claimed in **claim 68** (Art.33(2)).

41 Concerning independent **claim 69**, D1 discloses a first structure part (150) for use in an assembled structure (see point 34 above). Claim 69 is therefore not new (Art. 33(2)).

42 Turning to independent **claim 70**, D1 discloses a second structure part (100) for use in an assembled structure (see point 34 above). Claim 70 is therefore not new (Art. 33(2)).

43 We now turn to the independent **claim 71**. D4 (see Fig.3A-3E and corresponding text) discloses a method of manufacturing a first structure part (which could be used in the assembled structure shown in Fig.3A-3F or Fig.4 of D1), the method comprising the following steps:

1. providing a substrate (1 in Fig.3B of D4) having a first and a second part (6),
2. providing a means (5) for guiding light, the means defining an optical axis, and the means being positioned on the first part of the substrate and so as to be fixed in relation to the substrate and so that the optical axis is in a predetermined relation to the substrate (the resulting structure is shown in Fig.3D or 3E), and
3. providing an alignment element (below layer 6b) on the substrate, the alignment element being positioned:
   - i. on or above the second part (6) of the substrate, whereby
   - ii. the alignment element has an upper surface part in a fixed relationship to the first optical axis and the first plane (see also col.6, lines 17-34), and
   - iii. the first alignment element has a side surface part that is positioned in a predefined position in relation to the first optical axis (the position of the side surface of the alignment element below the layer 6b is determined by the position of the layer 6b with respect to the first optical axis, i.e. with respect to guiding means 5).

Claim 71 therefore is not new (Art. 33(2)).

44 In D4 (see Fig.3A, 3C and 3D),
- a first layer (2) is provided,
- a second layer (5) is provided, and
- a part of the second layer is removed.

Therefore, D4 (see col.6) also anticipates **claim 72** (Art.33(2)).

45 In D4, a third layer of a third material (etch stop 6b, see Fig.3B) is provided, so **claim 73** reads on D4 as well (Art.33(2)).

46 Concerning claim 74, D4 also discloses
- providing the second layer (5) also on the third layer (6b; this step leads to the structure part shown in Fig.3C), and
- the steps of:
  a) predefining the parts of the second layer (5) which should be removed, over the first part of the substrate (the light guiding means is predefined) and over the second part of the substrate (in the second part 6b, the layer 5 should be substantially removed),
  b) removing the predefined parts of the second layer (this step leads to the configuration shown in Fig.3D).

Claim 74 therefore reads on D4 (Art.33(2)).

47 Having regard to claim 75, D4 discloses the step of providing, at least over the first part of the substrate, a fourth layer (4) of a fourth material on the structure resulting after step b), the fourth material having a refractive index different from the second refractive index (this step leads to the configuration shown in Fig.3D). So **claim 75** is not new (Art.33(2)).

48 **Claim 76** and dependent **claims 77, 78** would not appear to be rendered obvious by the prior art presently available.

49 In the method disclosed in D4, in order to adjust the height of the alignment element (see Fig.2A or 3E), a skilled person could be expected to consider removing the remaining parts of the third layer above the second part of the substrate, since such a step of removing a layer is common in the art. **Claim 79** therefore does not appear to be inventive (Art.33(3)).

50 Moreover in the method of D4, the parts of the second layer which should be removed in the second layer (5 in Fig.3C) are, of course, predefined in a single step, since only a single feature (light guiding means 5 in Fig.3D) is to be fabricated. **Claim 80** therefore reads on D4 (Art.33(2)).

51 Insofar as **claim 81** can be understood (the reference of method claim 81 to claim 7, which claims a physical entity, is not clear), it reads on D4 (Art.33(2)): the method of D4 includes a removing step (RIE, see col.7, line 31, which leads to the structure part shown in Fig.3E), and also comprises the provision of a third layer (etch stop 6b, see col.9, lines 1-6).

52 Concerning independent **claim 82**, D1 discloses a method of assembling an assembled structure, the method comprising:

a. providing first and second structural parts (100 and 150 in Fig.3F, see also col.7 and col.6, respectively),

b. positioning the first and second structural parts in order to form the assembly (see col.8, lines 25-29), and

c. fixing the first and second structural parts to each other (see col.8, lines 29-30).

Claim 82 therefore is not new (Art. 33(2)).

(NB: It is clear from the analysis of the claims that the subject-matter of claims 11, 16, 23 and 76 is not found in the available prior art. However, claims 11, 16, 23 and 76 relate to quite different aspects of the cable disclosed in the application and apparently cannot form the basis of a series of independent claims since there would not be unity of invention (Rule 13).)

SECTION VIII:

When revising the claims it should be borne in mind that a plurality of independent claims of the same category should be avoided, in particular, claims that have been drafted as separate independent claims which effectively relate to the same subject-matter. Such claims lack conciseness and are contrary to Article 6.

SECTION VII:

1 The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

2 Any amendments should meet the requirements of Art 34(2)b PCT.

3 In order to facilitate the examination of the conformity of the amended application with the requirements of Article Art. 34(2)b PCT, the applicant is requested to clearly identify any amendments carried out and to indicate the passages of the application as filed on which these amendments are based.

PATENT COOPERATION TREATY

PLOUGMANN
VINGTOFT
& PARTNERS

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

26 OKT. 2001

CLT/AK

PCT

NOTIFICATION CONCERNING INFORMAL COMMUNICATIONS WITH THE APPLICANT

(PCT Rule 66.6)

To:

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Date of mailing *(day/month/year)* 24.10.2001

TRANSMITTAL FOR INFORMATION

Applicant's or agent's file reference
23339 PC 1

International application no.
PCT/DK00/00407

International filing date *(day/month/year)*
17/07/2000

Applicant
HYBRID MICRO TECHNOLOGIES ApS

An informal communication took place on 15/10/2001, between the International Preliminary Examining Authority and the applicant / the agent.

A copy of the note on that communication (Form PCT/IPEA/428) is herewith transmitted for your information.

Name and mailing address of the international preliminary examining authority
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Form PCT/IPEA/429 (july 1993)

Vertrag über die internationale Zusammenarbeit auf dem Gebiet des Patentwesens
Patent Cooperation Treaty
Traîté de coopération en matière de brevets

PCT

Application No.: PCT/DK00/00407

Note on an informal communication by telephone with the Applicant

A copy of this note is being sent to the Applicant for information

Participants

Applicant: --

Agent: Mr. Mörkbak

Examiner(s): Elflein, W

Summary of the communication

The examiner pointed out that the present telephone conversation is considered as an interview pursuing to the request filed in the letter of the applicant dated 26/9/2001, and relates to the amended set of claims submitted together with the letter of 26/9/2001. On the day of the interview, the attorney sent a telefax, the content of which was discussed during the interview. A copy of this telefax is attached to the present telephone minutes.

The examiner pointed out that the amended set of claims comprise various amendments that go beyond the subject-matter of the application as filed, that do however not appear to influence the discussion of novelty or inventive step. Moreover, claim 1 is rendered obvious by the documents D1, D4, and common knowledge. The examiner also pointed out that all the dependent claims 2-9 would not appear to be inventive.

With respect to claim 1, the disclosure of documents D1 and D4 were discussed. In particular, the attorney contested that D1 discloses or hints at a "single-mask process". No agreement was reached about whether claim 1 involves an inventive step. It was agreed upon that any further discussions should be postponed and the IPER should be issued. The examiner regretted that the previous favourable position with regard to inventive step pf certain subject-matter had to be withdrawn upon reconsideration of the case and that the IPER would therefore be negative.

Vertrag über die internationale Zusammenarbeit auf dem Gebiet des Patentwesens
Patent Cooperation Treaty
Traîté de coopération en matière de brevets

PCT

Application No.: PCT/DK00/00407

15/10/2001
.....
Date *(day / month / year)*

Elflein, W
.....
Authorized officer of IPEA

Enclosure(s):
Telefax dated 15.10.2001, consisting of three pages

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Copenhagen, 15 October 2001 Page 1 of 3 pages

From Nils Jakob Mørkbak

To Mr. Elflein
Of European Patent Office

International Patent Application No. PCT/DK00/00407
Hybrid Micro Technologies ApS
Optical hybridization
Our ref: 23339PC01

Artist Peter Nyborg

Dear Mr Elflein,

In response to out telephone interview earlier today, we hereby submit an outline for the subjects which we wish to discuss in the second part of our telephone interview later today. We will be referring to the present claims 1-9 as amended in response to the first written opinion.

Yours sincerely,

Plougmann, Vingtoft & Partners

Nils Jakob Mørkbak

D1 - 5,488,678
In Example 1 of D1 the formation of raised structures 155 and 162 as shown in Figure 3F is described (column 7 lines 10-64).

Example 1 relates to a ridge type waveguide structure, and the waveguide (as defined by raised structure 155) and the alignment feature 162 are at least in different material layers, between which there is no precise vertical alignment.

It is mentioned that the SiO_2 cladding layer 154 and the Si substrate 151 are processed simultaneously to form these structures (column 7 lines 39-45). The term *processed simultaneously to form* is used and in our opinion, the person skilled in the art would not perceive this term as defining structures 155 and 162 using a single mask step.

D4 - EP 0 807 838 A1
Figure 3A-E and corresponding description (column 6, line 5 to column 7, line 11) describes the fabrication of a waveguide coupling arrangement. A thin film layer to perform as an etch stop is deposited on top of a lower cladding layer 2. The thin film layer is structured by a photolithographic processing step to form portions 6b (Figure 3B). Possible materials for the thin film layer are disclosed in column 8, lines 20-22. Next, a second lower cladding layer 3 and a core layer 5 are deposited (Figure 3C). Possible materials for the core layer 5 are disclosed in column 8, lines 28-30. From Figure 3C to Figure 3D, a photolithographic processing step forms a waveguide core 5 in the core layer an upper cladding layer is deposited.

The processing of the thin film layer 6b and the processing of the core layer 5 can not be performed simultaneously since these are different materials which needs different processing (different etching). Moreover, the two layers, 6b and 5, are deposited on top of each other and separated by cladding layer 3. Therefore, simultaneous processing as disclosed in D1 to define the portions 6b and the waveguide core 5 is not feasible. Moreover, a single mask step as disclosed in claim 1 of the present application can not be applied.

D4 relates to a buried waveguide structure. The waveguide (defined and formed in core layer 5) and the alignment features 6b defined in thin film layer 6b are defined in different steps in different layers.

The present invention claims a method of production as outlined in Figures 2 through 9. Here, in Figure 5 and 6, it is shown how a part 18 of a core layer 16 for forming an optical waveguide core and parts 19 for defining a horizontal configuration of the first alignment feature(s) are defined by a single mask process in the same layer. The parts 19 are used in the step between Figure 5 and 6 to define a structuring of an etch stop layer 14 deposited before the core layer, in that the part of the etch stop layer not covered by the parts 19 are removed. The remaining parts of the etch stop layer (as seen in Figure 8) are now both vertically and horizontally aligned in relation to the waveguide core 18.

The method disclosed in D4 would require substantial modification to read onto the present claim 1. D1, firstly, relates to ridge wwaveguide structures and not buried waveguide structures, and secondly, does not teach the use of a single mask step. Moreover, neither of the references teaches how to define and form both structures 18 and 19 of Figure 5 of the present application in the same material layer, as claimed in claim 1, feature a) and b).

CLAIMS

1. A method of forming an assembly structure for assembling and aligning an optoelectronic device and an optical waveguide, said optical waveguide comprising a light input end for receiving light emitted from an output port of the optoelectronic device, said method comprising the steps of:

- providing a bottom cladding layer on top of a substrate, said bottom cladding layer comprising a first and a second part, wherein each part comprises a top and a bottom surface separated by a distance d,

- providing an etch stop layer on at least part of the second part of the bottom cladding layer,

- providing a core layer on top of the bottom cladding layer, said core layer extending on both the first and the second part of the bottom cladding layer thereby covering at least part of the etch stop layer, and

forming an optical waveguide and one or more first alignment features on the assembly structure by:

a) defining, by a single mask process, parts of the core layer for forming an optical waveguide core and for defining a horizontal configuration of the first alignment feature(s),

b) removing parts of the core layer not defined in step a), thereby forming the optical waveguide core in the core layer and defining the horizontal configuration of the first alignment feature(s) in the core layer, said optical waveguide thereby extending along a first optical axis in a plane and at a distance larger than or equal to d from the bottom surface of the first part of the bottom cladding layer

c) removing parts of the etch stop layer not covered by the core layer,

d) providing a top cladding layer so as to at least partly cover the optical waveguide core and optionally the parts of the core layer providing the horizontal configuration of the first alignment feature(s), and

e) etching into the structure over the second part of the bottom cladding layer to remove the top cladding layer, the core layer and parts of the second part of the bottom cladding layer not covered by the etch stop layer, thereby forming the first alignment feature(s) in the second part of the bottom cladding layer so that at least one top surface of the first alignment feature(s) is in essentially the same plane as the top surface of the first part of the bottom cladding layer, said formation of the first alignment feature(s) comprising the step of forming a first and a second tapered side surface part in directions at least substantially parallel to the first optical axis.

2. A method according to claim 1, wherein the optical waveguide extends on the top surface of the bottom cladding layer at a distance substantially equal to d above the bottom surface of the bottom cladding layer.

3. A method according to any of the preceding claims, further comprising the step of removing the etch stop layer defining the one or more alignment features formed in the bottom cladding layer.

4. A method according to any of the preceding claims, further comprising the step of arranging the optoelectronic device on top of the one or more alignment features so as to obtain vertical alignment of the output port of the optoelectronic device with the light input end of the optical waveguide.

5. A method according to any of the preceding claims, wherein one or more second alignment features are arranged on the bottom of the optoelectronic device, and wherein the step of aligning the output port of the optoelectronic device with the light input end of optical waveguide further comprises the step of abutting said second alignment feature(s) to the first and second tapered side surface parts of the first alignment feature(s) so as to obtain horizontal alignment.

6. A method according to any of the preceding claims, wherein step e) comprises etching by reactive ion etching.

7. A method according to any of the preceding claims, wherein the photonic device comprises a waveguide having a second optical axis and wherein the photonic devices are positioned so as to make the first optical axis and the second optical axis at least substantially parallel.

8. A method according to any of the preceding claims, further comprising soldering the optoelectronic device to one or more electrical contact pads formed beside the alignment features on exposed parts of the substrate.

9. A method according to any of the preceding claims, further comprising the steps of:

- forming, on the substrate, a ridge at least partly encircling the optoelectronic device,

- providing a lid, and

- soldering said lid to said ridge for sealing the optoelectronic device and the input end of the waveguide.

International Preliminary Examining Authority
European Patent Office
Erhardtstrasse 27
D-80298 München
Germany

26 SEP. 2001

PCT CHAPTER II

Copenhagen, 26 September 2001

International Patent Application No. PCT/DK00/00407
Hybrid Micro Technologies ApS
Optical hybridization
Our ref: 23339 PC 01

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Dear Sirs,

In response to the written opinion issued 13 August 2001, we hereby submit a new set of claims 1-9 to replace previous claims 1-82.

The new set of claims are directed to a method of forming an assembly structure according to the invention, and are based on previous claims 17-32. The basis for the new independent claim 1 may be found in the application as filed on page 9, line 24 through page 11, line 25, the previous claims 17 and 23, and Figs 2-9.

The Examiner cites references D1 and D4 as relevant prior art.

D1 discloses an assembly structure of an optical integrated circuit for assembling and aligning a semiconductor laser device with a waveguide. The alignment is performed by raised/recessed structures on the assembly structure and on the laser device. In the various embodiments, the vertical alignment of the laser device relies upon the thickness of various layers in the structure and therefore depends upon the precision to which such thickness can be controlled, e.g. by deposition, growth, etching or similar techniques.

In the assembly structure described in relation to Figure 3A-F in D1, a laser device 100 is aligned with a ridge-type waveguide using a raised structure 162. In this embodiment, the horizontal alignment is based on the formation of the ridge waveguide (ridge 155) and the raised structure 162.

Here, it should be noted that in D1, column 7, lines 39-44, it is mentioned that the second cladding layer 154 in the waveguide region 180 and the Si substrate 151 in the region 160 are processed simultaneously to form raised structures 155 and 162, respectively. However, this processing comprises an etching of the second cladding layer 154, which is a silicon dioxide layer, and an etching of the silicon substrate 151. Thus, two different materials, silicon dioxide and silicon, have to be etched, and such two different etching processes require several masks processes.

Thus, the horizontal configuration of the ridge 155 and the raised structure 162 are not defined by a single mask process.

It should also be noted that the process steps used in the fabrication of the assembly structure of Figure 3A-F are specific to ridge-type waveguides and do not apply to other waveguide types such as buried waveguides.

D4 discloses an optical waveguide coupling arrangement for buried waveguides and a fabrication process therefore. The fabrication process utilises a thin film for forming a reference plane in a height direction. However, there is no definite relation between the portions 6b and the waveguide core 5 as they are formed independently in different photolithographic steps with the deposition of a further cladding layer 3 there between (Please refer to Figures 3A-E and accompanying text).

Claim 1 in the present application relates to the formation of an assembly structure for assembling and aligning an optical device with a buried waveguide on the structure. The claimed method of formation provides an assembly structure with precise vertical *and* horizontal alignment of the buried waveguide with one or more alignment features. The method includes the steps of:

- defining the position of the waveguide and the alignment features in a single step so as to ensure a precise relative position of these, and
- forming the buried waveguide and the alignment features at the defined positions.

The claimed method is particular for the formation of buried-type waveguides as is evident from e.g. Figures 2-9 of the present application and accompanying text.

For these reasons, it is respectfully submitted that the claimed method is new and involves an inventive step over D1, D4 as well as a combination of these.

In case the Examiner does not agree that the new claims are properly based on the documents originally filed, and that the invention defined in the new claims is novel and involves an inventive step, a personal interview with the Examiner pursuant to Rule 66.6 PCT is requested prior to the issuance of a preliminary examination report.

Kindly acknowledge receipt of this letter by means of the enclosed form 1037.

Yours sincerely,

Plougmann, Vingtoft & Partners

Nils Jakob Mørkbak

Form 1037
New claims 1-11

CLAIMS

1. A method of forming an assembly structure for assembling and aligning an optoelectronic device and an optical waveguide, said optical waveguide comprising a light input end for receiving light emitted from an output port of the optoelectronic device, said method comprising the steps of:

- providing a bottom cladding layer on top of a substrate, said bottom cladding layer comprising a first and a second part, wherein each part comprises a top and a bottom surface separated by a distance d,

- providing an etch stop layer on at least part of the second part of the bottom cladding layer,

- providing a core layer on top of the bottom cladding layer, said core layer extending on both the first and the second part of the bottom cladding layer thereby covering at least part of the etch stop layer, and

forming an optical waveguide and one or more first alignment features on the assembly structure by:

a) defining, by a single mask process, parts of the core layer for forming an optical waveguide core and for defining a horizontal configuration of the first alignment feature(s),

b) removing parts of the core layer not defined in step a), thereby forming the optical waveguide core in the core layer and defining the horizontal configuration of the first alignment feature(s) in the core layer, said optical waveguide thereby extending along a first optical axis in a plane and at a distance larger than or equal to d from the bottom surface of the first part of the bottom cladding layer

c) removing parts of the etch stop layer not covered by the core layer,

d) providing a top cladding layer so as to at least partly cover the optical waveguide core and optionally the parts of the core layer providing the horizontal configuration of the first alignment feature(s), and

e) etching into the structure over the second part of the bottom cladding layer to remove the top cladding layer, the core layer and parts of the second part of the bottom cladding layer not covered by the etch stop layer, thereby forming the first alignment feature(s) in the second part of the bottom cladding layer so that at least one top surface of the first alignment feature(s) is in essentially the same plane as the top surface of the first part of the bottom cladding layer, said formation of the first alignment feature(s) comprising the step of forming a first and a second tapered side surface part in directions at least substantially parallel to the first optical axis.

2. A method according to claim 1, wherein the optical waveguide extends on the top surface of the bottom cladding layer at a distance substantially equal to d above the bottom surface of the bottom cladding layer.

3. A method according to any of the preceding claims, further comprising the step of removing the etch stop layer defining the one or more alignment features formed in the bottom cladding layer.

4. A method according to any of the preceding claims, further comprising the step of arranging the optoelectronic device on top of the one or more alignment features so as to obtain vertical alignment of the output port of the optoelectronic device with the light input end of the optical waveguide.

5. A method according to any of the preceding claims, wherein one or more second alignment features are arranged on the bottom of the optoelectronic device, and wherein the step of aligning the output port of the optoelectronic device with the light input end of optical waveguide further comprises the step of abutting said second alignment feature(s) to the first and second tapered side surface parts of the first alignment feature(s) so as to obtain horizontal alignment.

6. A method according to any of the preceding claims, wherein step e) comprises etching by reactive ion etching.

7. A method according to any of the preceding claims, wherein the photonic device comprises a waveguide having a second optical axis and wherein the photonic devices are positioned so as to make the first optical axis and the second optical axis at least substantially parallel.

8. A method according to any of the preceding claims, further comprising soldering the optoelectronic device to one or more electrical contact pads formed beside the alignment features on exposed parts of the substrate.

9. A method according to any of the preceding claims, further comprising the steps of:

- forming, on the substrate, a ridge at least partly encircling the optoelectronic device,

- providing a lid, and

- soldering said lid to said ridge for sealing the optoelectronic device and the input end of the waveguide.

PATENT COOPERATION TREATY

PCT

PLOUGMANN VINGTOFT & PARTNERS

26 MRS. 2001

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
23339 PC 1		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/DK 00/ 00407	17/07/2000	16/07/1999
Applicant		
HYBRID MICRO TECHNOLOGIES ApS		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 2 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language,** the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

[ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

[ ] contained in the international application in written form.

[ ] filed together with the international application in computer readable form.

[ ] furnished subsequently to this Authority in written form.

[ ] furnished subsequently to this Authority in computer readble form.

[ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

[ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

[X] the text is approved as submitted by the applicant.

[ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

[X] the text is approved as submitted by the applicant.

[ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 11

[X] as suggested by the applicant.

[ ] None of the figures.

[ ] because the applicant failed to suggest a figure.

[ ] because this figure better characterizes the invention.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK 00/00407

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G02B 6/42
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G02B, H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5488678 A (MOTOTAKA TANEYA ET AL), 30 January 1996 (30.01.96), column 5, line 56 - column 17, line 19, figures 3-6	1-82
A	EP 0864893 A2 (NIPPON TELEGRAPH AND TELEPHONE CORPORATION), 16 Sept 1998 (16.09.98), figures 12, 15,16,24	1-82

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 November 2000	23.03.01
Name and mailing address of the ISA/ European Patent Office Facsimile No.	Authorized officer Magnus Westöö/MP Telephone No.

S[redacted]2787

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/11/00

International application No.
PCT/DK 00/00407

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5488678 A	30/01/96	JP 7045811 A	14/02/95
EP 0864893 A2	16/09/98	JP 11287926 A	19/10/99

The demand must be filed directly with the competent International Preliminary Examining Authority or, if two or more Authorities are competent, with the one chosen by the applicant. The full name or two-letter code of that Authority may be indicated by the applicant on the line below:

IPEA/ EPO

PCT

CHAPTER II

DEMAND

under Article 31 of the Patent Cooperation Treaty:
The undersigned requests that the international application specified below be the subject of international preliminary examination according to the Patent Cooperation Treaty and hereby elects all eligible States (except where otherwise indicated).

UR

For International Preliminary Examining Authority use only

Identification of IPEA	Date of receipt of DEMAND

Box No. I IDENTIFICATION OF THE INTERNATIONAL APPLICATION

Applicant's or agent's file reference: 23339 PC 1

International application No.	International filing date *(day/month/year)*	(Earliest) Priority date *(day/month/year)*
PCT/DK00/00407	17 July 2000 (17.07.00)	16. July 1999 (16.07.99)

Title of invention: Hybrid integration of active and passive optical components on an SI-board

Box No. II APPLICANT(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

HYBRID MICRO TECHNOLOGIES ApS
c/o COM Center DTU
Akademivej 349
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Telephone No.:

Facsimile No.:

Teleprinter No.:

State *(that is, country)* of nationality: Denmark

State *(that is, country)* of residence: Denmark

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

KUHMANN, Jochen F.
Uglevej 9, 4. tv.
DK-2400 Copenhagen NV

State *(that is, country)* of nationality: Germany

State *(that is, country)* of residence: Denmark

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

POULSEN, Mogens Rysholt
Nordre Frihavnsgade 57, 4 th.
DK-2100 Copenhagen Ø

State *(that is, country)* of nationality: Denmark

State *(that is, country)* of residence: Denmark

☐ Further applicants are indicated on a continuation sheet.

International application No.
PCT/DK00/00407

Box No. III AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The following person is [X] agent [ ] common representative

and [X] has been appointed earlier and represents the applicant(s) also for international preliminary examination.

[ ] is hereby appointed and any earlier appointment of (an) agent(s)/common representative is hereby revoked.

[ ] is hereby appointed, specifically for the procedure before the International Preliminary Examining Authority, in addition to the agent(s)/common representative appointed earlier.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

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[ ] **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special addr ess to which correspondence should be sent.

Box No. IV BASIS FOR INTERNATIONAL PRELIMINARY EXAMINATION

Statement concerning amendments:*

1. The applicant wishes the international preliminary examination to start on the basis of:

[X] the international application as originally filed

the description [ ] as originally filed
[ ] as amended under Article 34

the claims [ ] as originally filed
[ ] as amended under Article 19 (together with any accompanying statement)
[ ] as amended under Article 34

the drawings [ ] as originally filed
[ ] as amended under Article 34

2. [ ] The applicant wishes any amendment to the claims under Article 19 to be considered as reversed.

3. [ ] The applicant wishes the start of the international preliminary examination to be postponed until the expiration of 20 months from the priority date unless the International Preliminary Examining Authority receives a copy of any amendments made under Article 19 or a notice from the applicant that he does not wish to make such amendments (Rule 69.1(d)). *(This check-box may be marked only where the time limit under Article 19 has not yet expired.)*

* Where no check-box is marked, international preliminary examination will start on the basis of the international application as originally filed or, where a copy of amendments to the claims under Article 19 and/or amendments of the international application under Article 34 are received by the International Preliminary Examining Authority before it has begun to draw up a written opinion or the international preliminary examination report, as so amended.

Language for the purposes of international preliminary examination: English

[X] which is the language in which the international application was filed.

[ ] which is the language of a translation furnished for the purposes of international search.

[X] which is the language of publication of the international application.

[ ] which is the language of the translation (to be) furnished for the purposes of international preliminary examination.

Box No. V ELECTION OF STATES

The applicant hereby **elects all eligible States** *(that is, all States which have been designated and which are bound by Chapter II of the PCT)*

excluding the following States which the applicant wishes **not to elect:**

Sheet No. . . 3

International application No.
PCT/DK00/00407

Box No. VI CHECK LIST

The demand is accompanied by the following elements, in the language referred to in Box No. IV, for the purposes of international preliminary examination:			For International Preliminary Examining Authority use only: received	not received
1. translation of international application	:	sheets	☐	☐
2. amendments under Article 34	:	sheets	☐	☐
3. copy (or, where required, translation) of amendments under Article 19	:	sheets	☐	☐
4. copy (or, where required, translation) of statement under Article 19	:	sheets	☐	☐
5. letter	:	1 sheets	☐	☐
6. other *(specify)*	:	sheets	☐	☐

The demand is also accompanied by the item(s) marked below:

1. [X] fee calculation sheet
2. [ ] separate signed power of attorney
3. [ ] copy of general power of attorney; reference number, if any:
4. [ ] statement explaining lack of signature
5. [ ] nucleotide and or amino acid sequence listing in computer readable form
6. [ ] other *(specify)*:

Box No. VII SIGNATURE OF APPLICANT, AGENT OR COMMON REPRESENTATIVE

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the demand).

Copenhagen, 14 February 2001

Nils Jakob Mørkbak

For International Preliminary Examining Authority use only

1. Date of actual receipt of DEMAND:
2. Adjusted date of receipt of demand due to CORRECTIONS under Rule 60.1(b):
3. [ ] The date of receipt of the demand is AFTER the expiration of 19 months from the priority date and item 4 or 5, below, does not apply. [ ] The applicant has been informed accordingly.
4. [ ] The date of receipt of the demand is WITHIN the period of 19 months from the priority date as extended by virtue of Rule 80.5.
5. [ ] Although the date of receipt of the demand is after the expiration of 19 months from the priority date, the delay in arrival is EXCUSED pursuant to Rule 82.

For International Bureau use only

Demand received from IPEA on:

PCT

17 JULI 2000

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only

International Application No.

International Filing Date

Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference *(if desired) (12 characters maximum)* 23339 PC 1

Box No. I TITLE OF INVENTION

Hybrid integration of active and passive optical components on a Si-board

Box No. II APPLICANT

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

HYBRID MICRO TECHNOLOGIES ApS
c/o COM Center DTU
Akademivej 349
DK-2800 Lyngby

☐ This person is also inventor.

Telephone No.

Facsimile No.

Teleprinter No.

State *(that is, country)* of nationality: Denmark

State *(that is, country)* of residence: Denmark

This person is applicant for the purposes of: ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

KUHMANN, Jochen F.
Uglevej 9, 4. tv.
DK-2400 Copenhagen NV

This person is:

☐ applicant only

☒ applicant and inventor

☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: Germany

State *(that is, country)* of residence: Denmark

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☒ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

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Teleprinter No.

☐ **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Continuation of Box No. III **FURT[illegible] APPLICANT(S) AND/OR (FURTHER) INVE[illegible]R(S)**

If none of the following sub-boxes is used, this sheet should not be included in the request.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

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Nordre Frihavnsgade 57, 4. th.
DK-2100 Copenhagen Ø

This person is:
☐ applicant only
☒ applicant and inventor
☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: Denmark

State *(that is, country)* of residence: Denmark

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:
☐ applicant only
☐ applicant and inventor
☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:
☐ applicant only
☐ applicant and inventor
☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:
☐ applicant only
☐ applicant and inventor
☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on another continuation sheet.

PCT

17 JULI 2000

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only

International Application No.

International Filing Date

Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference *(if desired) (12 characters maximum)* 23339 PC 1

Box No. I TITLE OF INVENTION

Hybrid integration of active and passive optical components on a Si-board

Box No. II APPLICANT

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

HYBRID MICRO TECHNOLOGIES ApS
c/o COM Center DTU
Akademivej 349
DK-2800 Lyngby

☐ This person is also inventor.

Telephone No.

Facsimile No.

Teleprinter No.

State *(that is, country)* of nationality: Denmark

State *(that is, country)* of residence: Denmark

This person is applicant for the purposes of: ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

KUHMANN, Jochen F.
Uglevej 9, 4. tv.
DK-2400 Copenhagen NV

This person is:

☐ applicant only

☒ applicant and inventor

☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: Germany

State *(that is, country)* of residence: Denmark

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☒ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

Plougmann, Vingtoft & Partners A/S
Sankt Annæ Plads 11
P.O. Box 3007
DK-1021 Copenhagen K

Telephone No. +45 33 63 93 00

Facsimile No. +45 33 63 96 00

Teleprinter No.

☐ **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Continuation of Box No. III FURT[illegible] APPLICANT(S) AND/OR (FURTHER) INVE[illegible]OR(S)

If none of the following sub-boxes is used, this sheet should not be included in the request.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

POULSEN, Mogens Rysholt
Nordre Frihavnsgade 57, 4. th.
DK-2100 Copenhagen Ø

This person is:
☐ applicant only
☒ applicant and inventor
☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: Denmark

State *(that is, country)* of residence: Denmark

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:
☐ applicant only
☐ applicant and inventor
☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:
☐ applicant only
☐ applicant and inventor
☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:
☐ applicant only
☐ applicant and inventor
☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on another continuation sheet.

See Notes to the request form

Box No.V DESIGNATION OF STATES

The following designations are hereby made under Rule 4.9(a) *(mark the applicable check-boxes; at least one must be marked)*:

Regional Patent

☒ **AP** **ARIPO Patent:** GH Ghana, GM Gambia, KE Kenya, LS Lesotho, MW Malawi, SD Sudan, SL Sierra Leone, SZ Swaziland, TZ United Republic of Tanzania, UG Uganda, ZW Zimbabwe, and any other State which is a Contracting State of the Harare Protocol and of the PCT

☒ **EA** **Eurasian Patent:** AM Armenia, AZ Azerbaijan, BY Belarus, KG Kyrgyzstan, KZ Kazakhstan, MD Republic of Moldova, RU Russian Federation, TJ Tajikistan, TM Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT

☒ **EP** **European Patent:** AT Austria, BE Belgium, CH and LI Switzerland and Liechtenstein, CY Cyprus, DE Germany, DK Denmark, ES Spain, FI Finland, FR France, GB United Kingdom, GR Greece, IE Ireland, IT Italy, LU Luxembourg, MC Monaco, NL Netherlands, PT Portugal, SE Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT

☒ **OA** **OAPI Patent:** BF Burkina Faso, BJ Benin, CF Central African Republic, CG Congo, CI Côte d'Ivoire, CM Cameroon, GA Gabon, GN Guinea, GW Guinea-Bissau, ML Mali, MR Mauritania, NE Niger, SN Senegal, TD Chad, TG Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT *(if other kind of protection or treatment desired, specify on dotted line)* .....

National Patent *(if other kind of protection or treatment desired, specify on dotted line)*:

☒ **AE** United Arab Emirates
☒ **AL** Albania .....
☒ **AM** Armenia .....
☒ **AT** Austria and utility model ....
☒ **AU** Australia .....
☒ **AZ** Azerbaijan
☒ **BA** Bosnia and Herzegovina .....
☒ **BB** Barbados
☒ **BG** Bulgaria .....
☒ **BR** Brazil .....
☒ **BY** Belarus .....
☒ **CA** Canada
☒ **CH and LI** Switzerland and Liechtenstein
☒ **CN** China .....
☒ **CR** Costa Rica .....
☒ **CU** Cuba .....
☒ **CZ** Czech Republic and utility model
☒ **DE** Germany and utility model ....
☒ **DK** Denmark and utility model ....
☒ **DM** Dominica
☒ **EE** Estonia and utility model .....
☒ **ES** Spain .....
☒ **FI** Finland and utility model ....
☒ **GB** United Kingdom
☒ **GD** Grenada
☒ **GE** Georgia .....
☒ **GH** Ghana .....
☒ **GM** Gambia
☒ **HR** Croatia .....
☒ **HU** Hungary .....
☒ **ID** Indonesia
☒ **IL** Israel .....
☒ **IN** India .....
☒ **IS** Iceland
☒ **JP** Japan .....
☒ **KE** Kenya .....
☒ **KG** Kyrgyzstan .....
☒ **KP** Democratic People's Republic of Korea .....
☒ **KR** Republic of Korea and utility model
☒ **KZ** Kazakhstan .....
☒ **LC** Saint Lucia
☒ **LK** Sri Lanka
☒ **LR** Liberia
☒ **LS** Lesotho .....
☒ **LT** Lithuania
☒ **LU** Luxembourg
☒ **LV** Latvia
☒ **MA** Morocco .....
☒ **MD** Republic of Moldova .....
☒ **MG** Madagascar .....
☒ **MK** The former Yugoslav Republic of Macedonia .....
☒ **MN** Mongolia
☒ **MW** Malawi .....
☒ **MX** Mexico .....
☒ **NO** Norway
☒ **NZ** New Zealand .....
☒ **PL** Poland .....
☒ **PT** Portugal .....
☒ **RO** Romania
☒ **RU** Russian Federation .....
☒ **SD** Sudan
☒ **SE** Sweden
☒ **SG** Singapore
☒ **SI** Slovenia .....
☒ **SK** Slovakia and utility model .....
☒ **SL** Sierra Leone .....
☒ **TJ** Tajikistan .....
☒ **TM** Turkmenistan .....
☒ **TR** Turkey .....
☒ **TT** Trinidad and Tobago .....
☒ **TZ** United Republic of Tanzania
☒ **UA** Ukraine .....
☒ **UG** Uganda .....
☒ **US** United States of America .....
☒ **UZ** Uzbekistan .....
☒ **VN** Viet Nam .....
☒ **YU** Yugoslavia .....
☒ **ZA** South Africa .....
☒ **ZW** Zimbabwe .....

Check-boxes reserved for designating States which have become party to the PCT after issuance of this sheet:

☒ DZ Algeria ☒ MZ Mozambique
☒ AG Antigua and Barbuda

Precautionary Designation Statement: In addition to the designations made above, the applicant also makes under Rule 4.9(b) all other designations which would be permitted under the PCT except any designation(s) indicated in the Supplemental Box as being excluded from the scope of this statement. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. *(Confirmation (including fees) must reach the receiving Office within the 15-month time limit.)*

Box No. VI PRIORITY CLAIM ☐ Further priority claims are indicated in the Supplemental Box.

Filing date of earlier application (day/month/year)	Number of earlier application	Where earlier application is: national application: country	regional application:* regional Office	international application: receiving Office
item (1) 16 July 1999 (16.07.99)	PA 1999 01040	Denmark		
item (2)				
item (3)				

☒ The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) *(only if the earlier application was filed with the Office which for the purposes of the present international application is the receiving Office)* identified above as item(s): (1)

* *Where the earlier application is an ARIPO application, it is mandatory to indicate in the Supplemental Box at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed (Rule 4.10(b)(ii)). See Supplemental Box.*

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) *(if two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used):*
ISA / EP

Request to use results of earlier search; reference to that search *(if an earlier search has been carried out by or requested from the International Searching Authority):*
Date *(day/month/year)* Number Country *(or regional Office)*

Box No. VIII CHECK LIST; LANGUAGE OF FILING

This international application contains the following **number of sheets**:

request	:	4
description (excluding sequence listing part)	:	32
claims	:	17
abstract	:	1
drawings	:	9
sequence listing part of description	:	
Total number of sheets	:	63

This international application is **accompanied** by the item(s) marked below:

1. ☒ fee calculation sheet
2. ☒ separate signed power of attorney
3. ☐ copy of general power of attorney; reference number, if any:
4. ☐ statement explaining lack of signature
5. ☐ priority document(s) identified in Box No. VI as item(s):
6. ☐ translation of international application into (language):
7. ☐ separate indications concerning deposited microorganism or other biological material
8. ☐ nucleotide and/or amino acid sequence listing in computer readable form
9. ☐ other *(specify)*:

Figure of the drawings which should accompany the abstract: 11

Language of filing of the international application: English

Box No. IX SIGNATURE OF APPLICANT OR AGENT

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).

Copenhagen, 17 July 2000

Plougmann, Vingtoft & Partners A/S

Niels Jakob Mørkbak

For receiving Office use only

1. Date of actual receipt of the purported international application:
2. Drawings: ☐ received: ☐ not received:
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:
4. Date of timely receipt of the required corrections under PCT Article 11(2):
5. International Searching Authority (if two or more are competent): ISA/
6. ☐ Transmittal of search copy delayed until search fee is paid.

For International Bureau use only

Date of receipt of the record copy by the International Bureau:

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

14

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
23339 PC 1		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/DK00/00407	17/07/2000	16/07/1999
International Patent Classification (IPC) or national classification and IPC G02B6/10		
Applicant HYBRID MICRO TECHNOLOGIES ApS		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 9 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 4 (2) sheets (document D6) sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
14/02/2001	24.10.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Elflein, W Telephone No. +49 89 2399 2820

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/DK00/00407

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1-32	as originally filed				

Claims, No.:

1-9	as received on	26/09/2001	with letter of	26/09/2001	

Drawings, sheets:

1/9-9/9	as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   ☐ the language of publication of the international application (under Rule 48.3(b)).
   ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   ☐ contained in the international application in written form.
   ☐ filed together with the international application in computer readable form.
   ☐ furnished subsequently to this Authority in written form.
   ☐ furnished subsequently to this Authority in computer readable form.
   ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:
   ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☒ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)
see separate sheet

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-9
	No:	Claims	
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1-9
Industrial applicability (IA)	Yes:	Claims	1-9
	No:	Claims	

2. Citations and explanations
see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION CONCERNING SUBMISSION OR TRANSMITTAL OF PRIORITY DOCUMENT

(PCT Administrative Instructions, Section 411)

To:

PLOUGMANN, VINGTOFT & PARTNERS A/S
Sankt Annæ Plads 11
P.O. Box 3007
DK-1021 Copenhagen K
DANEMARK

PLOUGMANN VINGTOFT & PARTNERS
24 NOV. 2000
N/M/LSC

Date of mailing (day/month/year) 16 November 2000 (16.11.00)	
Applicant's or agent's file reference 23339 PC 1	**IMPORTANT NOTIFICATION**
International application No. PCT/DK00/00407	International filing date (day/month/year) 17 July 2000 (17.07.00)
International publication date (day/month/year) Not yet published	Priority date (day/month/year) 16 July 1999 (16.07.99)
Applicant HYBRID MICRO TECHNOLOGIES APS et al	

1. The applicant is hereby notified of the date of receipt (except where the letters "NR" appear in the right-hand column) by the International Bureau of the priority document(s) relating to the earlier application(s) indicated below. Unless otherwise indicated by an asterisk appearing next to a date of receipt, or by the letters "NR", in the right-hand column, the priority document concerned was submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b).

2. This updates and replaces any previously issued notification concerning submission or transmittal of priority documents.

3. An **asterisk(*)** appearing next to a date of receipt, in the right-hand column, denotes a priority document submitted or transmitted to the International Bureau but not in compliance with Rule 17.1(a) or (b). In such a case, **the attention of the applicant is directed** to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

4. The **letters "NR"** appearing in the right-hand column denote a priority document which was not received by the International Bureau or which the applicant did not request the receiving Office to prepare and transmit to the International Bureau, as provided by Rule 17.1(a) or (b), respectively. In such a case, **the attention of the applicant is directed** to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

Priority date	Priority application No.	Country or regional Office or PCT receiving Office	Date of receipt of priority document
16 July 1999 (16.07.99)	PA 1999 01040	DK	15 Augu 2000 (15.08.00)

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 740.14.35

Authorized officer

C. Villet

Telephone No. (41-22) 338.83.38

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark
Office, PCT
2011 South Clark Place Room
CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 05 April 2001 (05.04.01)	
International application No. PCT/DK00/00407	**Applicant's or agent's file reference** 23339 PC 1
International filing date (day/month/year) 17 July 2000 (17.07.00)	**Priority date** (day/month/year) 16 July 1999 (16.07.99)
Applicant KUHMANN, Jochen, F. et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

14 February 2001 (14.02.01)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer Jean-Marie McAdams
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

Form PCT/IB/331 (July 1992) DK0000407

PATENT COOPERATION TREATY

PCT

From the INTERNATIONAL BUREAU

To:

PLOUGMANN & VINGTOFT A/S
Sankt Annæ Plads 11
P.O. Box 3007
DK-1021 Copenhagen K
DANEMARK

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

Date of mailing (day/month/year)
29 January 2002 (29.01.02)

Applicant's or agent's file reference
23339 PC 1

IMPORTANT NOTIFICATION

International application No.
PCT/DK00/00407

International filing date (day/month/year)
17 July 2000 (17.07.00)

1. The following indications appeared on record concerning:

[ ] the applicant [ ] the inventor [X] the agent [ ] the common representative

Name and Address
PLOUGMANN, VINGTOFT & PARTNERS A/S
Sankt Annæ Plads 11
P.O. Box 3007
DK-1021 Copenhagen K
Denmark

State of Nationality:
State of Residence:
Telephone No.: +45 33 63 93 00
Facsimile No.: +45 33 63 96 00
Teleprinter No.:

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

[ ] the person [X] the name [ ] the address [ ] the nationality [ ] the residence

Name and Address
PLOUGMANN & VINGTOFT A/S
Sankt Annæ Plads 11
P.O. Box 3007
DK-1021 Copenhagen K
Denmark

State of Nationality:
State of Residence:
Telephone No.: +45 33 63 93 00
Facsimile No.: +45 33 63 96 00
Teleprinter No.:

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

[X] the receiving Office
[ ] the International Searching Authority
[ ] the International Preliminary Examining Authority
[ ] the designated Offices concerned
[X] the elected Offices concerned
[ ] other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer
Jaime LEITAO

Telephone No.: (41-22) 338.83.38